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MATERIAL PROPERTIES HANDBOOK, VOLUME III.
MAGNESIUM NICKEL AND TITANIUM ALLOYS

Advisory Group for Aeronautical Research and Development
Paris, France

1967

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NORTH ATLANTIC TREATY ORGANIZATION
ADVISORY GROUP FOR AERONAUTICAL RESEARCH AND DEVELOPMENT

MATERIAL PROPERTIES HANDBOOK

VOLUME III

MAGNESIUM NICKEL AND TITANIUM ALLOYS

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for publication and
distribution

THE TECHNICAL DEPARTMENT
THE ROYAL AERONAUTICAL SOCIETY
4, HAMILTON PLACE, LONDON, W. 1

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for the Structures and Materials Panel of A.G.A.R.D.

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PREFACE

The charts in this Handbook have been prepared from basic data supplied by representatives appointed in each country, thus assuring that the information is the best available at the present time. These representatives are also responsible for the approval of their National Section, and the preparation of the Handbook has been possible only with their enthusiastic co-operation.

The representatives who assisted in the preparation of Volume III are:-

Belgium	- Lt. Col. A. Parot, Belgian Air Force
Canada	- H.V. Kinsey, Department of Mines & Technical Surveys
France	- J. Faguet, Service Technique Aeronautique
Germany	- Dr. Ing. K. Reichel, Stuttgart-Zuffenhausen
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Norway	- Capt. E. Tandberg, Royal Norwegian Air Force
United Kingdom	- F. Clifton, Royal Aircraft Establishment
United States	- D. Shinn, Wright Air Development Center

The charts will be reissued from time to time as additional or improved data become available, and it is envisaged that the Handbook may be extended at a later date to include other materials, in particular refractory metals.

Users of the Handbook are invited to comment to the Panel on the data or on the form of presentation, and consideration will be given to these comments in the preparation of further issues.



Richard V. Rhode,

Chairman
Structures and Materials Panel

February 1963

*Volume III
Magnesium,
Nickel &
Titanium Alloys*

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February 1963

INTRODUCTION TO VOLUME III

PURPOSES AND USES OF THE HANDBOOK

A thorough knowledge of relevant material properties is a fundamental requirement of efficient aircraft design. Furthermore, a careful comparison of different materials, and particularly materials produced by different countries, is often of great value when considering manufacture under licence, modification or repair. Much of the basic information necessary for such a comparison is already available, although it is often widely scattered. The purpose of this Handbook therefore, is to collect the available information on aircraft materials produced by the nations of the NATO alliance, and to present this information in a consistent and systematic form.

In addition to its uses as a standard reference book, this Handbook could be used as an aid in the comparison of test results and in the comparison of the engineering practices of the various NATO nations. It could also be used to give an indication of some unknown property of a material by comparison with other similar materials whose relevant properties are known.

It is hoped that an outcome of the establishment of a standard format will be to encourage producers and others in all the NATO nations to record material properties in this form.

SCOPE OF VOLUME III OF THE HANDBOOK

This third volume of the Handbook deals with those magnesium, nickel and titanium alloys which are of most interest for structural use in aircraft of the NATO nations. Nickel and titanium alloys which are used only for castings or for rivets have not been included. However, a large proportion of magnesium alloy is used in the cast form and magnesium casting alloys have been included in this volume. This has necessitated the introduction of a classification of three types of test for use in the *Static Properties* charts. The classification is explained on p.3 of this Introduction.

The nations for which data are included in this first issue are Canada, France, Germany, Italy, the Netherlands, the United Kingdom and the United States. It has been established that none of the other NATO nations produce magnesium, nickel or titanium alloys which are used structurally in aircraft.

GENERAL LAYOUT

The data are divided into *National Sections*, each section dealing with the alloys produced by one country.

In each *National Section* there is, for each distinct alloy, or group of alloys, a set of sheets which give data on the physical and mechanical properties, both at room and elevated temperatures. Preceding these sheets are *Introductory Notes* which give general information and amplify such points as the designations and specifications of the alloys, heat treatment, testing procedures and other information which it is not practicable to include on the charts. It is advisable that these Notes should be read carefully before using any of the charts.

To facilitate the addition of information a loose leaf format has been adopted.

PRESENTATION OF DATA

The data are presented in tabular rather than graphical form. This presentation has the merit of simplicity, the data take up less space and modifications or alterations are simple to carry out. Where variation of properties with respect to two or more variables is involved, the choice of the most suitable variable as the abscissa will depend on the use to which the data are to be put; the tabular presentation leaves the user free in this choice. Also, when plotting curves for a specific purpose it is a simple matter to convert the units when working from tabulated values.

The wording on the charts is kept to a minimum, symbols replacing words wherever possible. The presentation is such that little, if any, translation will be required.

Any information which is non-standard, or any points which need stressing are dealt with by footnotes, references to which are displayed around the edges of the charts and apply to rows or columns.

NOTATION AND UNITS

The *Notation* chart given at the end of this Introduction shows the symbols used for the various properties. In each *National Section* a notation acceptable by that nation is used, and the chart enables comparison of the various notations used.

The units, which are quoted on every chart, are those used by the country of origin of the alloy. A chart giving *Conversion Scales* enables easy and rapid conversion from one system of units to another. This chart follows the *Notation* chart at the end of this Introduction.

DATA BASIS

On all the sheets giving mechanical properties, there is a statement on the statistical basis of the information. This is given as Data Basis 'A', 'B' or 'C' at the top of each sheet. The coding for each statistical basis is:-

- A - minimum guaranteed values, i.e. the values listed are the minimum to be expected.
- B - 90% probability values, i.e. the values listed will be met or exceeded by 90% of the material supplied.
- C - Typical (basis for typicality not specified).

The preferred basis is 'B', 90% probability values, but if these values are not available the order of preference is first Data Basis 'A' and then 'C'.

TYPES OF TEST FOR CASTINGS

In the *Static Properties* charts for magnesium castings the properties are given for three types of test which are distinguished by the letters 'a', 'b' and 'c' on the charts. The significance of these is as follows.

- a - Tests on special separately cast test specimens.
- b - Tests to find the minimum properties of castings using specimens cut from various locations in production castings.
- c - Tests to find the average properties throughout castings using specimens cut from various locations in production castings.

The results of each type of test may be given to 'Data Basis A, B or C' as defined under 'Data Basis' in this *Introduction*.

The manner in which these properties are applied for design purposes varies considerably. In general the castings are designed and accepted on the basis of one or more of the following procedures, depending on the importance or degree of complication of the component.

- 1) Acceptance by calculation
- 2) Acceptance by tests on complete production castings loaded in a manner representative of working conditions
- 3) Acceptance by tests on specimens cut from castings
- 4) Acceptance by radiological or other defect detection methods.

The properties used when designing by procedure (1) are either those from 'Type of Test: a' with a reduction factor, or those from 'Type of Test: b'. When procedures (2) and (3) are followed, the properties from 'Types of Test: b and c' are required. Procedure (4) is used alone only for lightly stressed parts, but great importance is attached to this when used in conjunction with the other procedures, particularly in the case of complicated castings. 'Type of Test: a' properties are also of value in the comparison of the properties of alloys from different countries.

DATA PRESENTED

For each distinct alloy or group of alloys a set of charts is given which include, for various forms and conditions of the alloy, information on the chemical composition and physical and mechanical properties at room and at elevated temperatures. A complete list of the properties covered is given at the end of these notes. For some of the alloys dealt with, the complete range of data is not yet available.

The *General Properties* chart gives the chemical composition of the alloy by quoting the limits of each alloying element as a percentage by weight of the total, with either upper and lower limits or an upper limit only.

The *General Properties* chart also gives selected physical properties of the alloy at room temperature and at elevated temperatures.

The *Static Properties* charts state the relevant official specifications and group the properties at room temperature according to form, heat treatment condition and thickness of the material. Two or three rows are included for some of the properties so that variation with grain direction or other parameters may be noted.

For a number of applications the shape of the compression stress-strain curve, up to about the 0.5 per cent offset yield stress, is of interest. Thus rather than present a large number of typical curves, values of the 0.1, 0.2 and 0.5 per cent offset yield stresses in compression are quoted. These values, together with the value of the Modulus of Elasticity in compression, may be used, in a method such as that given in the Royal Aeronautical Society Structures Data Sheets 00.02.00, 00.02.04 and 00.02.05, to provide information relevant to the shape of the stress-strain curve.

For the *Fatigue Properties* chart, reliable results have been selected from tests on specimens subject to various loading conditions. Brief descriptions of the test specimens are given on each chart, and further information is given in the *Introductory Notes* to the relevant *National Section*.

On the *Short Time Properties at Elevated Temperature* chart and the *Recovered Properties after Exposure to Elevated Temperature* chart, the mechanical properties after various times of exposure are expressed as percentages of their values at room temperature. The room temperature property on which these percentages are based and the temperature at which it applies are quoted when known at the head of the column. In general, data are included for temperatures up to the maximum working temperature.

The charts which give data on creep are headed *Properties under Load and Elevated Temperature*. The first sheet gives, as percentages of the ultimate tensile stress, the stresses required to produce specified total deformations after various times at elevated temperatures. A second sheet gives, as percentages of the ultimate tensile stress, the stresses required to produce specified minimum creep rates at various temperatures, and also the stresses required to cause tensile failure in a specified time at various temperatures. As for the other elevated temperature charts, the room temperature reference properties are given on the charts when known.

LIST OF PROPERTIES

The properties included on the charts are listed below. The properties are listed in the order in which they appear for each alloy and are grouped under the title of the relevant chart.

GENERAL PROPERTIES

Chemical composition

Physical properties

- Density
- Specific heat
- Thermal conductivity
- Coefficient of thermal expansion
- Emissivity

STATIC PROPERTIES

- Ultimate stress in tension
- Offset yield stress in tension
- 0.1 per cent offset yield stress in compression
- 0.2 per cent offset yield stress in compression
- 0.5 per cent offset yield stress in compression
- Ultimate shear stress
- Ultimate bearing stress
- Yield stress in bearing
- Modulus of elasticity in tension
- Modulus of elasticity in compression
- Shear modulus
- Ultimate elongation

FATIGUE PROPERTIES

- Rotating bending test
- Reversed flexure test
- Repeated axial load test
- Alternating torsion test

SHORT TIME PROPERTIES AT ELEVATED TEMPERATURES

- Ultimate tensile stress
- Offset yield stress in tension
- 0.2 per cent offset yield stress in compression
- Ultimate shear stress
- Yield stress in bearing
- Elastic modulus

RECOVERED PROPERTIES AFTER EXPOSURE TO ELEVATED TEMPERATURE

- Ultimate tensile stress
- Offset yield stress in tension
- 0.2 per cent offset yield stress in compression
- Ultimate shear stress

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

- Time to creep to various deformations
- Minimum creep rate
- Time to tensile failure

February 1963

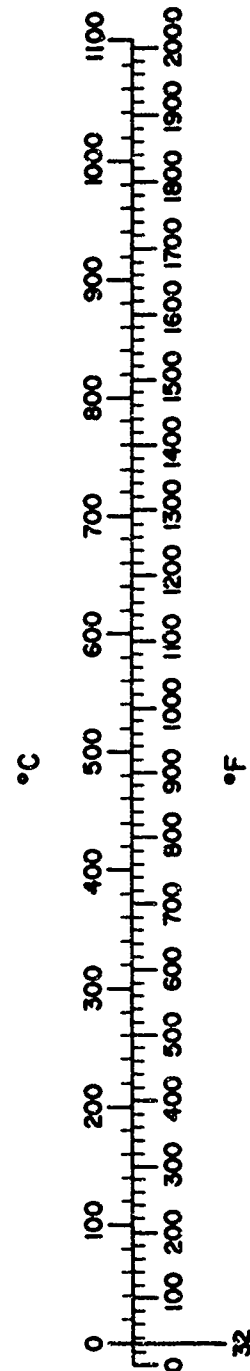
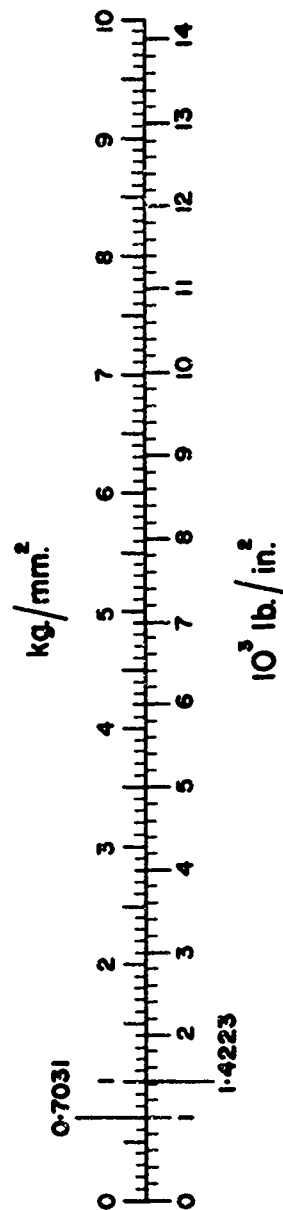
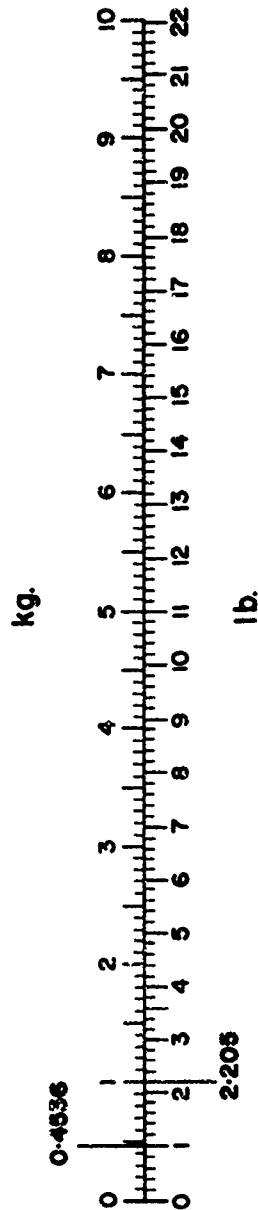
Iss. N°	4		
DATE	Feb. 1962		
App'd by	A.T.		

PROPERTY		CANADA	FRANCE	GERMANY	ITALY	NORWAY	UNITED KINGDOM	UNITED STATES OF AMERICA
Ultimate Stress in Tension		F_{tu}	R	σ_B	R	σ_B	f_1	F_{tu}
0.1 per cent. {Proof Stress Offset Yield Stress} in Tension							t_1	
0.2 per cent. " " " in Tension		F_{ty}	$E_{0.2}$	$\sigma_{0.2}$	$S_{0.2}$	$\sigma_{0.2}$	t_2	F_{ty}
0.1 per cent. " " in Compression		F_{cl}	$E_{c0.1}$		$S_{c(0.1)}$		C_1	F_{cl}
0.2 per cent. " " " in Compression		F_{cy}	$E_{c0.2}$	$\sigma_{dFO.2}$	$S_{dFO.2}$		C_2	F_{cy}
0.5 per cent. " " " in Compression		F_{c5}	$E_{c0.5}$	$\sigma_{dFO.5}$	$S_{dFO.5}$		C_5	F_{c5}
Ultimate Shear Stress		F_{su}	R_c	τ	τ_R	τ	f_q	F_{su}
Ultimate Bearing Stress		F_{bru}		σ_L	σ_s		f_b	F_{bru}
Yield Stress in Bearing		F_{bry}			S_s		b_{10}	F_{bry}
Modulus of Elasticity in Tension		E	M	E	E	E	E	E
" " " " Compression		E_c	M_c	E_d	E_c		E_c	E_c
Shear Modulus or Modulus of Rigidity		G	G	G	G	G	G	G
Ultimate Elongation		e	A	δ	A	δ	e	e
Specific Weight		ω	δ	γ	γ	γ	ω	ω
Specific Heat		c	c	c	c	c	c	c
Thermal Conductivity		K	K	λ	K	λ	k	K
Coefficient of Thermal Expansion		α	α	α	α	α	α	α
Temperature		T	θ	T	T	T	T	T
Time at Temperature		t	t	t	t	t	t	t
Emissivity		ϵ	ϵ	ϵ	ϵ	ϵ	ϵ	ϵ

NOTATION

CONVERSION SCALES

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DATE	July 1968	Oct. 1969	March 1971	9 '62
App'd by	J.C.S.	J.B.	J.B.	A.T.



CANADIAN SECTION

Volume III
Magnesium,
Nickel &
Titanium Alloys

CANADIAN SECTION

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1. Introductory Notes.
2. Charts as given in the table below.

<i>Magnesium Alloys</i>	<i>Title of Chart</i>	<i>Issue No.</i>	<i>Date</i>
AZ 91	General Properties	1	Feb. 1962
	Static Properties	1	"
EZ 33	General Properties	1	"
	Static Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
HZ 32	General Properties	1	"
	Static Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
ZK 61	General Properties	1	"
	Static Properties	1	"

March 1962

CANADIAN SECTION INTRODUCTORY NOTES

The *Introduction to Volume III* of this Handbook explains the general layout adopted for the presentation of the data, together with details of properties considered and the explanation of various terms. The purpose of the following notes is to amplify these points, where necessary, in relation to those Canadian alloys which are included.

DESIGNATION

The designations of the Canadian magnesium alloys are descriptive of the composition of the material. The designation consists of an initial group of letters indicating the main alloying elements followed by numbers which signify the approximate average percentage content of each of these elements.

The letters used to indicate elements are as follows:-

A - Aluminium	K - Zirconium
E - Rare Earth Metals	Z - Zinc
H - Thorium	

Thus EZ33 is a magnesium alloy containing 3 per cent rare earth metals and 3 per cent zinc.

SPECIFICATIONS

As for all the National Sections, the specifications appropriate to the various forms and conditions of the alloys are indicated on the *Static Properties* charts wherever possible.

CSA specifications are issued by:-

Canadian Standards Association,
235 Montreal Road,
Ottawa 2,
Ontario, Canada.

There is at present no CSA specification for HZ32 alloy, and the properties quoted are appropriate to the commercial specifications B50 T16B - S4 (aged) issued by the General Electric Company and GT - M - 4 (stabilised) issued by Orenda Engines, Ltd.

MATERIALS COVERED

This Section of the Handbook lists the available established data on those magnesium casting alloys produced in Canada which are most widely used in aircraft construction.

CHEMICAL COMPOSITION

The General Properties charts give the chemical composition by quoting the limits of the alloying elements as a percentage by weight of the total.

CONDITION

The 'Condition' row on the charts refers to the type of heat treatment and conditioning. The conditions of the various alloys are indicated on the charts by symbols which have the same meaning as those used in the United States section. The symbols used in the Canadian section are as follows:-

- T5 - Artificially aged only.
- T6 - Solution heat treated and then artificially aged.
- T7 - Solution heat treated and then stabilised.

NOTATION

The notation used in this Section of the Handbook for the various physical and mechanical properties of Canadian alloys is defined in the *Notation Chart* in the *Introduction to Volume III*. This chart also compares the notations used for the other National Sections. Points where any amplification is needed are dealt with under the appropriate headings below.

UNITS

The units used for the various parameters and properties are indicated on each of the charts. For mechanical properties the stresses and moduli are given in units of 10^3 lb/in^2 , whilst temperature is quoted in degrees Centigrade. For conversion to other units see the *Conversion Scales* chart given in the *Introduction to Volume III*.

DATA BASIS

The *Introduction to Volume III* of this Handbook describes the use of the symbols 'A', 'B' and 'C' denoting the data basis of the values for the various properties given on the charts. Special aspects of this in relation to the values quoted for the Canadian alloys are outlined below.

- A - This indicates that the values listed are minimum guaranteed properties, i.e. specification properties.
- B - Insufficient data are available to quote Data Basis 'B' values for any of the Canadian alloys.
- C - This indicates that the values listed are typical for the material, there being insufficient data to determine values for basis 'A' or 'B'.

In general the data basis used on any chart is shown at the top of the chart, but special attention must be paid to footnotes which sometimes indicate a different basis for some particular part of the chart.

STATIC PROPERTIES CHARTS

Tensile strength properties are given for three types of test distinguished by the letters 'a' 'b' or 'c' in the row labelled 'Type of Test'. The significance of these symbols is explained below.

TYPE OF TEST

- a - This indicates that the values listed are for separately cast test specimens.
- b - This indicates that the values listed are the minimum for any single specimen cut from a critical area of an actual casting.
- c - This indicates that the values listed are the average of at least four test bars cut from any area of an actual casting.

ELEVATED TEMPERATURE DATA

On these charts the data are presented as percentages of the appropriate room temperature values, which are indicated when known in brackets at the head of the column. The initials R.T. signify that the data were obtained from tests conducted at an unspecified room temperature.

GENERAL PROPERTIES

CANADA
AZ 91
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn										Mg
Sand Casting	8.3 9.3	0.4 1.0	0.13 Min.										Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			R.T.				
ω	gm./cm. ³		1.81				
c	cal./(gm.°C)						
K	cal.cm/(cm. ² sec. °C)						
α	per °C x 10 ⁻⁶						
ϵ							

Iss. No.	Date	App'd by
1	FEB '82	A.T.

**CANADA
AZ 91
Magnesium Alloy**

Units: 10^3 lb./in.^2

Iss. No.	1		
Date	FEB '62		
App'd by	A.T.		

Foot notes	Form	Sand Casting
	Specification	CSA-HG.9
	Condition	T6
	Thickness (in.)	
	Cross-Sectional Area (or weight)	
	Type of Test	a b c
	F_{tu}	34
	F_{ty}	16
	F_{cl}	
	F_{cu}	
	F_{cs}	
	F_{su}	
	F_{bru}	
	F_{bry}	
	E	
	E_c	
	G	
	e	3
	Footnotes	

GENERAL PROPERTIES

CANADA
EZ 33
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Zr	Rare Earths										Mg
Sand Casting	2.5 4.0	0.5 1.0	2.5 4.0										Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			R.T.				
ω	gm./cm. ³		1.83				
c	cal./(gm.°C)						
K	cal.cm/(cm. ² sec. °C)						
α	per °C x 10 ⁻⁶						
ϵ							

Iss. No.	1		
Date	FEB 62		
App'd by	A.T.		

Iss. No.	1		
Date	FEB '82		
App'd by	A.T.		

Data Basis: A

Units: 10^3 lb./in.^2

STATIC PROPERTIES (SHEET)

CANADA
EZ 33
Magnesium Alloy

Footnotes	Form	Sand Casting											
	Specification	CSA-HG.9											
	Condition	T 5											
	Thickness (in.)												
	Gross - Sectional Area (or weight)												
	Type of Test	a	b	c									
	F_{Tu}	20	18										
	F_{Ty}	13	11.5										
	F_{Tl}												
	F_{Ty}												
F_{Cs}													
F_{Cu}													
F_{bru}													
F_{bry}													
E													
E_c													
G													
e	%	2	2										
Footnotes													

CANADA
EZ 33
Magnesium Alloy

Units: hours, °C, 10³lb./in.²

Iss. No.	1		
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[illegible]

GENERAL PROPERTIES

CANADA
HZ 32
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Th	Zr	Zn										Mg
Sand Casting Specification B50T16B-34	2.5 4.0	0.5 1.0	1.7 2.5										Remainder
Sand Casting Specification GT-M-4	2.7 3.3	0.6 1.0	2.1 2.6										Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			R.T.				
ω	gm./cm. ³		1.83				
c	cal./(gm.°C)						
K	cal.cm/(cm. ² sec. °C)						
α	per °C x 10 ⁻⁶						
ϵ							

Iss. No.	Date	App'd by
1	Feb 1962	AT

(SHEET)

CANADA
HZ 32
Magnesium Alloy

Units: 10^3 lb./in.^2

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Date	FEB '82		
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Form	Sand Casting					
	B50 T16 B-S4	GT-M-4				
Specification						
Condition	T5	T7				
Thickness (in.)						
Cross - Sectional Area(or weight)						
Type of Test	a	b	c	a	b	c
F _{tu}	27	20		27	24.3	
F _{ty}	13	10		12	10.8	
F _{cl}						
F _{cy}						
F _{cs}						
F _{su}						
F _{bru}						
F _{bry}						
E						
E _c						
G						
e %	4	3		5	4.5	
Footnotes						

**CANADA
HZ 32
Magnesium Alloy**

Units: hours, °C., 10³lb./in.²

Iss. No.	1		
Date	FEB '82		
App'd by	A.T.		

[illegible]
$$(1) F_{ty} = 8.8 \times 10^3 \text{ lb./in.}^2$$

GENERAL PROPERTIES

CANADA
ZK 61
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Zr											Mg
Sand Casting	5.5 - 6.5	0.6 Min.											Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			R.T.				
ω	gm./cm. ³		1.83				
c	cal./(gm.°C)						
K	cal.cm./(cm. ² sec. °C)						
α	per °C x 10 ⁻⁶						
ϵ							

I	FEB '52	A.T.
Iss. No.	Date	App'd by

Iss. No.	I	
Date	FEB 82	
App'd by	A.T.	

Data Basis: A

Units: 10^3 lb./in.^2

Footnotes	Form	Sand Casting												
	Specification	CSA-HG.9												
	Condition	T6												
	Thickness (in.)													
	Cross-Sectional Area (or weight)													
	Type of Test		a	b	c									
	F_{tu}		42	40	34									
	F_{ty}		26	26	24									
	F_{cl}													
	F_{cy}													
	F_{cs}													
	F_{su}													
	F_{bru}													
	F_{bry}													
	E													
	E_c													
	G													
	e	%	5	5	3									
	Footnotes			(1)	(1)									

(1) Data Basis: C

STATIC PROPERTIES (SHEET)

CANADA
ZK6I
Magnesium Alloy

FRENCH SECTION

CONTENTS

1. Introductory Notes.
2. Charts as given in the table below.

<i>Magnesium Alloys</i>	<i>Title of Chart</i>	<i>Issue No.</i>	<i>Date</i>
G-A9	General Properties Static Properties	1 1	June 1961 "
G-Z4Tr	General Properties Static Properties	1 1	" "
G-Z5Zr	General Properties Static Properties	1 1	" "
G-Tr3Z	General Properties Static Properties	1 1	" "
G-Z6H	General Properties Static Properties	1 1	" "
G-H3Z	General Properties Static Properties	1 1	" "
G-A7Z1	General Properties Static Properties	1 1	" "
G-A3Z1	General Properties Static Properties	1 1	" "

Cont...

CONTENTS Continued

<i>Nickel Alloys</i>	<i>Title of Chart</i>	<i>Issue No.</i>	<i>Date</i>
N-K20CDAT	General Properties	1	June 1961
	Static Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature, Sheet 1	1	"
	Properties under Load and Elevated Temperature, Sheet 2	1	"
N-C20KTA	General Properties	1	"
	Static Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature, Sheet 1	1	"
	Properties under Load and Elevated Temperature, Sheet 2	1	"
<i>Titanium Alloys</i>			
T-A4M	General Properties	1	"
	Static Properties	1	"
	Fatigue Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature, Sheet 1	1	"
	Properties under Load and Elevated Temperature, Sheet 2	1	"
T-A6V	General Properties	1	"
	Static Properties	1	"
	Fatigue Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature	1	"

June 1961

Volume III
Magnesium,
Nickel, &
Titanium
Alloys

FRENCH SECTION

INTRODUCTORY NOTES

The *Introduction to Volume III* of this Handbook explains the general layout adopted for the presentation of data, together with details of the properties considered and the explanation of various terms. The purpose of the following notes is to amplify these points, where necessary, in relation to those French alloys which are included.

DESIGNATION OF ALLOYS

In general the designation of the alloys is based on their mean chemical composition. The designation consists of a series of letters and numbers.

The first letter indicates the basic element (G : magnesium, N : nickel, T : titanium).

The group of letters and numbers which follows is separated from the first letter by a hyphen. The letters indicate the most important alloying elements, arranged in order of decreasing percentage content. The average percentage content by weight of a principal alloying element is indicated by a number following the symbol for that element.

The symbols used are as follows:

A - aluminium	N - nickel
C - chromium	S - silicon
D - molybdenum	T - titanium
Fe - iron	Tr - rare earths
G - magnesium	U - copper
H - thorium	V - vanadium
K - cobalt	Z - zinc
M - manganese	

As a rule, only the percentage of the first of the principal elements is mentioned, the percentage of the others only being added to resolve any ambiguity with a similar alloy.

e.g. T - A6V is titanium alloy containing about 6% of aluminium with some vanadium.

SPECIFICATIONS

The specifications appropriate to the various alloys are indicated on the *Static Properties* charts except where the mechanical properties requirements are based on time to tensile failure at elevated temperature, when the specifications are given in a footnote to the appropriate *Properties under Load and Elevated Temperature* chart.

The AIR specifications are issued by:

Ministère de la Défense Nationale et des Forces Armées,
Secrétariat d'Etat aux Forces Armées (AIR)

and copies can be obtained from:

Service de Documentation et d'Information Technique,
Bureau des Ventes,
2 Avenue de la Porte d'Issy,
Paris XVIe.

AICMA specifications are issued by:

Association Internationale des Constructeurs de Matériel Aéronautique,
6 Rue Galilée,
Paris XVIIe.

However not all the alloys are covered by AIR or AICMA specifications. Others which are not yet standardised are included in the Handbook since they are used widely for aircraft construction in France.

ALLOYS COVERED

This Section of the Handbook lists the available established data on eight magnesium alloys, two nickel alloys, and two titanium alloys which are widely used in aircraft construction in France. The materials covered, together with the forms in which they are produced are listed below. The designations in brackets are also in common use.

MAGNESIUM ALLOYS

G-A9	- sand castings
G-Z4Tr (R-Z5)	- sand castings
G-Z5Zr (Z-5Z)	- sand castings
G-Tr3Z (ZRE1)	- sand castings
G-Z6H (T-Z6)	- sand castings
G-H3Z (ZTI)	- sand castings
G-A7Z1	- tubes, extrusions
G-A3Z1	- Sheet, plate, tubes, extrusions

NICKEL ALLOYS

N-K20CDAT	- bars, forgings
N-C20KTA	- bars, forgings

TITANIUM ALLOYS

T-A4M	- bars, forgings
T-A6V	- bars, forgings, sheet

CHEMICAL COMPOSITION

The chemical composition of alloys covered by an AIR Specification is given in the *General Properties* charts by quoting the limits of the alloying elements as a percentage by weight of the total. In those cases where an alloy has not been standardised, the upper and lower limits in common use have been quoted. In other cases, the analysed composition of the material used in the mechanical properties tests has been given.

CONDITION

The 'Condition' row on the charts refers to the type of heat treatment and conditioning. The conditions are given in the French form on the charts in order to avoid slight changes in meaning that might occur with translation.

An indication of the meaning of the terms used is given below, and details of the temperatures and times of the various treatments for particular alloys are given in the table.

Brut de filage dressé - As extruded, straightened
 Dur - Hard
 Homogénéisé - Homogenised
 Hypertrempé - Quenched or Solution Treated at high temperature
 Recuit - Annealed
 Revenu - Tempered or Aged
 Traité - Heat Treated
 Trempé - Quenched or Solution Treated
 Vieilli - Aged

	Alloy	Condition	Heating	Cooling
Magnesium Alloys	G-A9	Homogénéisé	24 hrs. at 400°C	Air quench
	G-Z4Tr	Vieilli artificiellement	2 hrs. at 330°C followed by 16 hrs. at 175°C	Air cooled
	G-Z5Zr	Vieilli artificiellement	12 hrs. at 175°C	Air cooled
	G-Tr3Z	Vieilli artificiellement	16 hrs. at 175°C	Air cooled
	G-Z6H	Vieilli artificiellement	2 hrs. at 330°C followed by 16 hrs. at 200°C	Air cooled
	G-H3Z	Vieilli artificiellement	16 hrs. at 330°C	Air cooled

Table continued

	Alloy	Condition	Heating	Cooling
Nickel Alloys	N-C20KTA	Hypertrempé, Revenu	4 hrs. at 1150°C Followed by 8 hrs. at 1080°C 16 hrs. at 700°C	In Air In still air
	N-K20 CDAT	Hypertrempé, Revenu	1½ hrs. at 1200°C 16 hrs. at 850°C	In Air In still Air
Titanium Alloys	T-A6V	Recuit	1 hr. at 700°C	
		Trempé, Revenu	at 850°C 2 hrs. at 480°C	Water quench In still air
	T-A4M	Recuit	1 hr. at 700°C	

NOTATION

The notation used in this Section of the Handbook for the various physical and mechanical properties of the French alloys is defined in the *Notation* chart in the *Introduction to Volume III*. This chart also compares the notations used for the other National Sections. Points where any amplification is needed are dealt with under the appropriate headings below.

UNITS

The units used for the various parameters and properties are indicated on each of the charts. For mechanical properties, the stresses and moduli are given in kg./mm²., whilst temperature is quoted in degrees Celsius. For conversion to other units see the *Conversion Scales* chart given in the *Introduction to Volume III*.

DATA BASIS

The symbols 'A' and 'C' denoting the data basis of the values for the various properties given on the charts of the French Section are explained below.

A - This indicates that the values listed are the minimum to be expected for the given material.

C - This indicates that the values listed are typical for the material, there being insufficient data to determine values for basis 'A' or 'B'.

As explained in the *Introduction to Volume III* the preferred basis is 'B', i.e. values which will be met or exceeded by 90% of the material supplied. This data basis is not used on the French charts.

In general the data basis used on any chart is shown at the top of the chart, but special attention must be paid to the footnotes which sometimes indicate a different data basis for some particular part of the chart.

TENSILE STRENGTH

The 0.2 per cent offset yield stress in tension is given and is denoted by the symbol $E_{0.2}$.

The sub-headings 'L' and 'LT' used on the *Static Properties* charts refer to the longitudinal and long-transverse directions respectively.

The tensile properties ($R, E_{0.2}, A\%$) are obtained from test pieces selected and preferred in accordance with the appropriate clauses of 'La Norme NF A 03-1011, obtainable from

L'Association Française de Normalisation (AFNOR),
23, Rue Notre Dame des Victoires,
PARIS 2^e.

ELONGATION

The values of elongation given on the charts are quoted as the percentage elongation, at fracture, of the gauge length. For each alloy the values are given from measurements using a gauge length of $8.16\sqrt{S_0}$ where S_0 is the initial cross-sectional area of the test specimen. For details of this test, reference should be made to 'La Norme NFA 03-101'.

However for some alloys a gauge length of $5.65\sqrt{S_0}$ was used and this is indicated by a footnote on the appropriate chart.

FORGINGS

The Strength properties of forgings can vary markedly, but the values quoted give an indication of the level of strength that might be expected in a simple forging. The properties given for the nickel alloy forgings refer particularly to turbine blades. For details of testing and inspection of forgings, reference should be made to the specification AIR 3385.

CASTINGS

The *Static Properties* charts give data for castings for two types of test specimen. These are distinguished by the letters 'a' and 'b' in the row designated 'Type of Test'. The significance of these values is indicated below.

'a' - This indicates that the values given are the properties for separately cast test specimens.

'b' - This indicates that the values given are the properties for specimens cut from castings in an area specified by the designer.

The properties of separately cast test specimens are not used for design purposes, being normally used only for foundry control. However they are of interest for the comparison of the properties of alloys, particularly between those of countries which have different methods of arriving at design values for specimens cut from castings.

It should be noted that there is often a considerable variation in mechanical properties between different areas of a casting. This variation depends largely on the local rate of cooling, which is influenced by such factors as the local thickness, the pouring temperature, the method of feeding, etc. However, it has been found that by careful design and control of foundry technique it is possible to obtain consistently the properties quoted under 'Type of Test : b' in a specified area of the casting.

In other areas of the casting, over which no special precautions have been taken, the properties may not reach these values. For this reason, and also because many castings are very complicated and not amenable to accurate calculation of the stresses, great emphasis is placed on the examination of the castings by radiographic means and on break-up tests of sample castings.

Full information on the French requirements and procedure for the manufacture and testing of castings for aeronautical applications may be found in the publication AIR 3380 entitled 'Instruction relative aux Pièces de Fonderie Destinées aux Constructions Aeronautiques'.

Copies may be obtained from:

Service de Documentation et d'Information Technique,
Bureau des Ventes,
2, Avenue de la Porte d'Issy,
PARIS XVIe.

FATIGUE PROPERTIES

The *Fatigue Properties* charts give data from rotating bending and repeated axial loading tests. The type of specimen is indicated briefly on the charts, and details of the geometry and the elastic concentration factors K_t , for the notches are given below.

The rotating bending tests were carried out on smooth round specimens of two shapes.

- 1) Smooth specimen TGM (torique grand modèle) - large toroidal pattern

Minimum diameter of specimen = 6.5 mm.
Radius of generating circle = 105 mm.

- 2) Smooth specimen CPM (conique petit modèle) - small conical pattern.

Diameter of section of maximum stress = 4.66 mm.
Semi-angle at apex of cone = $2^{\circ}30'$.

The repeated axial loading tests were performed on smooth and notched flat plate specimens.

- 1) Smooth waisted Schenk specimen ($K_t = 1.05$)

Width = 10 mm.
Radius at root of waist = 62.5 mm.

2) Notched Schenk specimen. ($K_t = 2$)

Width outside notch = 14 mm.
Width at root of notch = 10 mm.
Radius at root of notch = 2 mm.

3) Notched Schenk specimen, ($K_t = 2$)

Width outside notch = 14 mm.
Width at root of notch = 10 mm.
Radius at root of notch = 0.62 mm.

In all cases, the Nominal Maximum Stress' quoted on the charts is the maximum stress across the critical section of the specimen, determined at the maximum load of the fatigue cycle, without correction for stress concentration effects. The 'Stress Ratio' quoted on the charts is the ratio of minimum to maximum stress during the fatigue cycle with compressive stress being taken negative, and tensile stress positive.

It should be noted that there is always a wide scatter of results with tests of this type, and the values given on the charts represent mean lines through the scatter bands.

ELEVATED TEMPERATURE DATA

On these charts the data are presented as percentages of the appropriate room temperature values. The room temperature value is given in kg./mm², together with the value of 'room temperature' in °C, in brackets at the head of each column.

The elevated temperature tensile test pieces and those used for the room temperature tests are identical, conforming to 'La Norme NF A 03-101' with a gauge length $l_0 = 8.16 \sqrt{S_0}$ except for the titanium alloys when the AICMA specimens are used with a gauge length of $5.65 \sqrt{S_0}$. In all cases the tests were conducted with a strain rate of between 0.001 and 0.002 mm. per mm. per minute.

For the *Properties under Load and Elevated Temperature* charts, the data were obtained from test pieces in accordance with the specification AIR 0820. The creep data presented on these charts give the stresses (expressed as percentages of the room temperature values of R) which, at a given temperature, will lead

- 1) to a permanent deformation of 0.2%
 - and 2) to rupture
- at the end of the period of time indicated.

It should be noted that the creep deformation quoted is the permanent deformation, and does not include elastic extension or thermal expansion.

Some specifications, for alloys for high temperature service, base the strength requirements on time to tensile failure at given temperatures and stresses, rather than on the room temperature tensile properties. In such cases the actual stresses, instead of percentages of the room temperature values, are quoted on the *Time to Tensile Failure* charts. The Data Basis is 'A', and the specific number is quoted in a footnote.

GENERAL PROPERTIES

FRANCE
G-A9
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Al	Mn	Zn	Si	Fe	Ni						Mg
Casting	0.2 Max.	7.5 9.0	0.15 0.6	0.2 1.0	0.3 Max.	0.05 Max.	0.01 Max.						Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	gm./cm. ³	All Conditions	1.8				
C	cal./(gm.°C)	All Conditions	0.24	0.24			
K	cal.cm/(cm. ² sec. °C)	Homogénéisé	0.12				
α	per °C x 10 ⁻⁶	Homogénéisé	27.2	27.2	27.2		

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1	June 1964	A.T.

(SHEET)

Magnesium Alloy

Data Basis: A

Units: kg./mm.²

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GENERAL PROPERTIES

FRANCE
G-Z4Tr
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Al	Mn	Zn	Si	Fe	Ni	Zr	Rare Earths				Mg
Casting	0.03 Max.	0.02 Max.	0.15 Max.	3.5 5.0	0.01 Max.	0.01 Max.	0.005 Max.	0.4 1.0	0.75 1.75				Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	gm./cm. ³	All Conditions	1.84				
C	cal./(gm.°C)	All Conditions	0.23	0.23			
K	cal.cm./(cm. ² sec. °C)	Vieilli	0.27				
α	per °C x 10 ⁻⁶	Vieilli	27.1	27.1	27.1		

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1	June 1961	A.T.

(SHEET)

Magnesium Alloy

Units: kg./mm.²

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Date	June 1964		
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#	Form	Sand Casting
1	Specification	AIR 3380 and AICMA
2	Condition	Veilli artificiellement
3	Thickness	
4	Gross Sectional Area.	
5	Type of Test	a b
6	R	21 18
7	E _{0.2}	15 13
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21	M	4400
22	M _c	
23	G	1650
24	A %	3 2
25	Footnotes	

GENERAL PROPERTIES

FRANCE
G-Z5Zr
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Al	Mn	Zn	Si	Fe	Ni	Zr					Mg
Casting.	0.03 Max.	0.02 Max.	0.15 Max.	3.5 5.5	0.01 Max.	0.01 Max.	0.005 Max.	0.4 1.0					Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	gm./cm. ³	All Conditions	1.81				
C	cal./(gm.°C)	All Conditions	0.23	0.23			
K	cal.cm./(cm. ² sec. °C)	vieilli	0.20				
α	per °C x 10 ⁻⁶	vieilli	27.3	27.3	27.3		

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GENERAL PROPERTIES

FRANCE
G-Tr 3Z
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Al	Mn	Zn	Si	Fe	Ni	Zr	Rare Earths				Mg
Casting	0.03 Max.	0.02 Max.	0.15 Max.	0.8 — 3.0	0.01 Max.	0.01 Max.	0.005 Max.	0.4 — 1.0	2.5 — 4.0				Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	gm./cm. ³	All Conditions	1.80				
C	cal./(gm.°C)	All Conditions	0.25	0.25			
K	cal.cm/(cm. ² sec. °C)	Vieilli	0.24				
α	per °C x 10 ⁻⁶	Vieilli	26.8	26.8	26.8		

Iss. No.	Date	App'd by
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FRANCE
G-Tr3Z
Magnesium Alloy

Data Basis: A

Units: kg./mm.²

Iss. No.	1		
Date	June 1961		
App'd by	A T		

Form	Sand Casting
Specification	AIR 3380 and AICMA
Condition	Vielli artificiellement.
Thickness	
Cross - Sectional Area	
Type of Test	a b
R	14 12
Eoz	10 9
M	4400
M _c	
G	1650
A %	3 2
Footnotes	

GENERAL PROPERTIES

FRANCE
G-26H
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Al	Mn	Zn	Si	Fe	Ni	Zr	Th	Rare Earths			Mg
Sand Casting	0.03 Max.	0.02 Max.	0.15 Max.	5.0 6.0	0.01 Max.	0.01 Max.	0.005 Max.	0.4 1.0	1.5 2.3	0.2 Max.			Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	gm./cm. ³	All Conditions	1.87				
C	cal./(gm.°C)	All Conditions	0.23	0.23			
K	cal.cm/(cm. ² sec. °C)	Veilli	0.26				
α	per °C x 10 ⁻⁶	Veilli	27.1	27.1	27.1		

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GENERAL PROPERTIES

FRANCE
G-H3Z
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Al	Mn	Zn	Si	Fe	Ni	Zr	Th	Rare Earths			Mg
Casting	0.03 Max.	0.02 Max.	0.15 Max.	1.7 2.5	0.01 Max.	0.01 Max.	0.005 Max.	0.4 1.0	2.5 4.0	0.1 Max.			Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	gm./cm. ³	All Conditions	1.83				
C	cal./(gm.°C)	All Conditions	0.23	0.23			
K	cal.cm./cm. ² sec. °C	Veilli	0.25				
α	per °C x 10 ⁻⁶	Veilli	26.7	26.7	26.7		

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Date			
App'd by			

GENERAL PROPERTIES

FRANCE
G-A7Z1
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Ni	Cu	Fe				Others		Mg
											Each	Total	
All Forms	6.5 8.5	0.5 1.5	0.12 Min.	0.3 Max.	0.005 Max.	0.05 Max.	0.007 Max.				0.3 Max.	— —	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	gm./cm. ³	All Conditions	1.8				
C	cal./(gm.°C)	All Conditions	0.24	0.24			
K	cal.cm/(cm. ² sec. °C)	Annealed	0.12				
α	per °C x 10 ⁻⁶	Annealed	27.3	27.3	27.3		

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GENERAL PROPERTIES

FRANCE
G-A3Z1
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu	Ni	Fe				Others		Mg
											Each	Total	
All Forms	2.5 3.5	0.5 1.5	0.2 Min.	0.3 Max.	0.05 Max.	0.005 Max.	0.007 Max.				0.3 Max.	— —	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	gm./cm. ³	All Conditions	1.77				
C	cal./(gm.°C)	All Conditions	0.25	0.25			
K	cal.cm/(cm. ² sec. °C)	Annealed	0.18				
α	per °C x 10 ⁻⁶	Annealed	26	26	26		

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Date			
App'd by			

GENERAL PROPERTIES

FRANCE
N-K20CDAT
Nickel Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	Mn	Cr	Mo	Al	Ti	Co						Ni
All Forms	0.22	0.06	11.14	4.10	3.9	1.38	20.06						Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
	gm./cm. ³						
	cal./[(gm.°C)						
	cal.cm./[cm. ² sec. °C)						
	per °C x 10 ⁻⁶						

DATE	JUNE 1961	App'd	by
		A.T.	

Iss. No.	1	Date	JUNE 1961
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FRANCE
N-K20CDAT
Nickel Alloy

Data Basis: C

Units: hrs., °C., kg./mm².

Form	Bars and Forgings.															
Condition	Hypertrempe, revenu.															
t →	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
θ ↓	Per Cent F (22.7 at 20°C)		Per Cent E _{0.2} (89.4 at 20°C)													
800	65	73														
850	57	59														
900	47	45														
950	36	29														
1000	25	17														
1050	13	5.6														

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET 1)

**FRANCE
N-K20CDAT
Nickel Alloy**

Units: hrs., °C., kg./mm²

Data Basis: C

CREEP DATA

Form		Bars and Forgings.													
Condition		Hypertrempé, revenu.													
t →		10	20	30	40	50	60	70	80	90	100	110	120	130	140
θ ↓	Permanent Deformation Per Cent	Per Cent R (122.7 at 20°C)													
800	0.2	33	24												
850	0.2	21	15												
900	0.2	12	8.6												
950	0.2	6.5	4.3												
1000	0.2	3.4	1.7												
1050	0.2	1.1													

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**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET 2)

**FRANCE
N-K20CDAT
Nickel Alloy**

Units: hours, °C., kg./mm²

Data Basis: C

MINIMUM CREEP RATE

Form												
Condition												
Creep Rate												
↓												

TIME TO TENSILE FAILURE

Form	Bars and Forgings.											
Condition	Hypertrempé, revenu.											
t →		15		300								
T ↓	Per Cent R (122.7 at 20°C)											
800		41		30								
850		29		19								
900		19		11								
950		11		5.9								
1000		6.1		2.9								
1050		2.4		1.1								

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GENERAL PROPERTIES

FRANCE
N-C20KTA
Nickel Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	Si	Mn	Cr	Al	Ti	Co	Cu	Fe				
All Forms	0.12 Max.	1.5 Max.	1 Max.	18 21	0.7 1.8	1.8 3	15 21	0.1 Max.	2 Max.				

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
	gm./cm. ³						
	cal./(gm.°C)						
	cal.cm./(cm. ² sec. °C)						
	per °C x 10 ⁻⁶						

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FRANCE
N-C20KTA
Nickel Alloy

Units: kg./mm².

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Foot Notes	Form	Bars and Forgings.
	Specification	
	Condition	Hypertrempé, revenu.
	Thickness	
	Cross - Sectional Area	
	R	100
	E _{0.2}	70
	E _{0.1}	
	E _{0.2}	
	E _{0.5}	
	R _c	
	M	
	M _c	
	G	
	A%	
	Footnotes	

FRANCE
N-C20KTA
Nickel Alloy

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Data Basis: C

Units: hrs, °C, kg./mm.²

Form	Bars and Forgings.															
Condition	Hypertrempé, revenu.															
t →																
θ ↓	Per Cent R Per Cent E ₀₂ (100 at 20°C) (70 at 20°C)															
750		64								63						
800		55								54						
850		42								43						
900		32								31						
950		24								21						
1000		17								12						
1050		12								5.4						

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET 1)

**FRANCE
N-C20KTA
Nickel Alloy**

Units: hrs., °C., kg./mm².

Data Basis: C

CREEP DATA

Form		Bars and Forgings.													
Condition		Hypertrempé, revenu.													
→		15	30												
↓	Permanent Deformation Per Cent	Per cent R (100 at 20°C)													
750	0.2	38	25												
800	0.2	27	16												
850	0.2	16	8												
900	0.2	9	3.5												
950	0.2	4.6	1												
1000	0.2														
1050	0.2														

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**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET 2)

**FRANCE
N-C20KTA**
Nickel Alloy

Units: hrs., °C., kg/mm²

Data Basis: C

MINIMUM CREEP RATE

Form												
Condition												
Creep Rate												
$\theta \downarrow$												

TIME TO TENSILE FAILURE

Form	Bars, Forgings.						All Forms					
Condition	Hypertrempé, revenu.						Hypertrempé, revenu.					
t →			15		300				5	8		
$\theta \downarrow$	Per Cent R (100 at 20°C)						Stress (kg./mm. ²) ⁽¹⁾					
750			42		30							
800			32		21				27 ⁽²⁾			
850			21		13							
900			13.5		9							
950			8		3.5				8			
1000			4.4		1.6							
1050			2.1									

(1) N.B Data Basis: A, Specification AIR 9170. (2) At 815°C

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GENERAL PROPERTIES

FRANCE
T-A4M
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	Si	Mn	Al	Fe								Ti
All Forms	0.08 Max.	0.04 Max.	3.5 5.0	3.5 5.0	0.15 Max.								Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
	gm./cm. ³						
	cal./(gm.°C)						
	cal.cm/(cm. ² sec. °C)						
	per °C x 10 ⁻⁶						

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Data Basis: A

Units: kg./mm².

Form	Bars, Forgings, Sheet.
Specification	AICMA
Condition	Recuit
Thickness	
Cross - Sectional Area	95-115
R	
E _{0.2}	85
E _{CO.1}	
E _{CO.2}	
E _{CO.5}	
R _c	
M	
M _c	
G	
A	% 10
Footnotes	

(1) Gauge length = $5.65\sqrt{S_0}$

FRANCE
T-A4M
Titanium Alloy

Titanium Alloy

Units: kg./mm.².

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[illegible]

FRANCE
T-A4M
Titanium Alloy

Units: hrs., °C., kg./mm.²

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**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET 1)

**FRANCE
T-A4M**
Titanium Alloy

Units: hrs., kg./mm.², °C.

Data Basis: C

CREEP DATA

Form		Bars, Forgings, Sheet.															
Condition		Recuit															
t →				n	300												
θ ↓	Permanent Deformation Per Cent	Per cent R (94.6 at 20°C)															
400	0.2			44	25												
450	0.2			19	11												
500	0.2			6.4	3.4												
550	0.2			1.6													
600	0.2																

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PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE
(SHEET 2)

FRANCE
T-A4M
Titanium Alloy

Units: hrs., °C., kg./mm²

Data Basis: C

MINIMUM CREEP RATE

Form															
Condition															
Creep Rate															
$\theta \downarrow$															

TIME TO TENSILE FAILURE

Form	Bars, Forgings, Sheet.														
Condition	Recuit														
$t \rightarrow$		15		300											
$\theta \downarrow$	Per Cent R (94.6 at 20°C)														
400		63		59											
450		51		34											
500		32		17											
550		16		6.3											
600		8.5		3.2											

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GENERAL PROPERTIES

FRANCE
T-A6V
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	V	Al	Fe									Ti
All Forms	0.08 Max.	3.5 4.5	5.5 7.0	0.25 Max.									Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
	gm./cm. ³						
	cal./(gm.°C)						
	cal.cm/(cm. ² sec. °C)						
	per °C x 10 ⁻⁶						

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STATIC PROPERTIES
(SHEET)

FRANCE
T-A6V
Titanium Alloy

Data Basis: A

Units: kg./mm.²

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Form	Bars, Forgings and Sheet.
Specification	AICMA
Condition	Recut
Thickness	
Cross-Sectional Area	
R	90-110
E _{0.2}	82
E _{0.1}	
E _{0.2}	
E _{0.5}	
R _c	
M	
M _c	
G	
A	% 10
Footnotes	

(1) Gauge length = 5.65 $\sqrt{S_0}$

FRANCE
T-A6V
Titanium Alloy

FRANCE
T-A6V

Titanium Alloy

Units: kg./mm.²

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[illegible]

FRANCE
T-A6V
Titanium Alloy

Iss. No.	1		
Date	June 1946		
App'd by	AT		

Data Basis: C

Units: hrs., °C., kg./mm.².[illegible]

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET)

**FRANCE
T-A6V
Titanium Alloy**

Units: hrs., °C., kg./mm²

Data Basis: C

CREEP DATA

Form		Bars, Forgings and Sheet.															
Condition		Recult															
t →		-	0	8													
θ ↓	Permanent Deformation Per Cent	Per Cent R (103·5 at 20°C)															
350																	
	0·2	63	61	59													
400																	
	0·2	58	52	47													
450																	
	0·2	47	37	29													

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GERMAN SECTION

GERMAN SECTION

INTRODUCTORY NOTES

The *Introduction to Volume III* of this Handbook explains the general layout adopted for the presentation of the data, together with details of the properties considered and the explanation of various terms. The purpose of the following notes is to amplify these points, where necessary, in relation to those German alloys which included.

MAGNESIUM ALLOY SPECIFICATION AND DESIGNATION

In Germany, for the wrought magnesium alloys, the specification and designation given to a material consist of the letter W followed by a Group of four figures, e.g. W3504.

For the cast magnesium alloys the specification and designation given to a material consists of a group of five figures, e.g. 3.5194. The first figure '3' indicates that the material is a light alloy. The group of four figures, separated from the first figure by a dot, is the designation of each particular alloy. For materials for aeronautical use, the last figure of the five figure designation is always '4'.

MATERIALS COVERED

MAGNESIUM ALLOYS

This Section of the Handbook lists the available established data on four wrought magnesium alloys and six cast magnesium alloys. These magnesium alloys are the ten most widely used structurally in aircraft.

The designations of the magnesium alloys covered, together with the forms in which they are produced are listed below:

W3501 - Sheet; tubes; extruded shapes	Gas weldable corrosion resistant magnesium alloy with very good machining and good hot-forming characteristics.
W3504 - Sheet	Argonarc weldable magnesium alloy with very good machining and good hot-forming characteristics.
W3510 - Tubes; extruded shapes	Hot-formable magnesium alloy with very good machining characteristics.
W3515 - Drawn and extruded rods; die forgings	Magnesium alloy with very good machining characteristics.

3.5104 - Sand castings

Casting magnesium alloy specially suitable for compact castings e.g. undercarriage struts. For temperatures up to 100°C. Not weldable.

3.5114 - Sand castings

High strength magnesium casting alloy suitable for bulky structural parts and hydraulic pressure vessels. Argonarc weldable.

3.5194 - Sand castings; permanent
mould castings; pressure
die castings

High Strength magnesium casting alloy for temperatures up to 100°C. Argonarc weldable.

3.6104 - Sand castings

Magnesium casting alloy suitable for bulky structural parts and pressure vessels at temperatures up to 150°C. Argonarc weldable.

3.6204 - Sand castings

Creep-resistant Mg. alloy suitable for gas turbine housings and structural parts where strength at temperatures up to 250°C is required. Argonarc weldable.

3.6254 - Sand castings

Creep-resistant Mg. alloy suitable for gas turbine housing and parts where high strength at temperatures in the region of 250-320°C is required. Argonarc weldable.

NICKEL AND TITANIUM

A range of nickel and titanium alloys is produced in Germany for use in aircraft construction and charts giving the properties of these materials will be issued when the necessary data are available. The following nickel and titanium alloys used in German aircraft construction are similar to the U.K. and U.S. alloys shown. The user is referred to the data presented in the U.K. and U.S. Sections.

	<i>German Designation</i>	<i>Form</i>	<i>Similar to:</i>	<i>Specification</i>
<i>Nickel Alloy</i>	2.4630	Sheet; strip; bars; tubing	D. T. D. 703B (U.K.)	D. T. D. 703B
<i>Titanium Alloy</i>	3.7164	Bars; forgings; shapes	6Al-4V (U.S.)	Mil-T-9047 Cl. 5

CHEMICAL COMPOSITION

The *General Properties* charts give the chemical composition by quoting the limits of the alloying elements as a percentage by weight of the total.

It should be noted that for the alloys containing zirconium the limits quoted are for 'available' zirconium, i.e. that quantity of zirconium which is soluble in dilute hydrochloric acid.

CONDITION

The 'Condition' row on the charts refers to the type of heat treatment and condition. The designation used with German magnesium alloys is a numerical system. The number follows the alloy specification number and is separated from it by a dot, e.g. 3.5194.8. The numbers designating the condition have the following meanings:

WROUGHT MAGNESIUM ALLOYS

- 0 - as fabricated
- 1 - soft (O)
- 2 - half hard
- 3 - hard
- 4 - solution heat treatment followed by natural ageing at room temperature to a substantially stable condition (T4)
- 5 - solution heat treatment followed by strain hardening (T3)
- 6 - solution heat treatment followed by stretch relieving
- 7 - solution heat treatment followed by artificial ageing (T6)
- 8 - hard drawn
- 9 - special treatment

For reference purposes the equivalent U.S. designation is included in brackets.

CAST MAGNESIUM ALLOYS

The condition designations for casting alloys have recently been revised but the new system is so far only in use for the alloys 3.5104 and 3.5114. The following table gives the meanings of the condition number for the two systems.

Condition Number	For alloys 3.5104 and 3.5114	For Alloys 3.5194, 3.6104, 3.6204 and 3.6254
0	As cast	Sand castings
1	Soft	
2		
3		
4	Naturally aged, or quenched or homogenized	Permanent mould castings
5		
6	Artificially aged	
7		Pressure die castings
8	Stress relieved	
9	Special treatment, e.g. Stabilized	

NOTATION

The notation used in this Section of the Handbook for the various physical and mechanical properties of the German alloys is defined on the *Notation* chart in the *Introduction to Volume III*. This chart also compares the notations used for the other National Sections. Points where any amplification is needed are dealt with under the appropriate headings below.

UNITS

The units used for the various parameters and properties are indicated on each of the charts. For mechanical properties the stresses and the moduli are given in kg./mm^2 , whilst temperatures are quoted in degrees centigrade. For conversion to other units see the *Conversion Scales* chart given in the *Introduction to Volume III*.

DATA BASIS

The symbols 'A' and 'C' denoting the data basis of the values for the various properties given on the charts of the German Section are explained below:

- A - This indicates that the values listed are the minimum to be expected for the given material.
- C - This indicates the values listed are typical for the material, there being insufficient data to determine values for basis A.

No data to basis B are available for the German alloys.

In general the data basis used on any chart is shown at the top of the chart, but special attention must be paid to the footnotes which sometimes indicate a different basis for some particular part of the chart.

TENSILE STRENGTH

The tensile properties are obtained from test pieces selected and prepared in accordance with DIN50125 for material in bar form and with DIN 50114 for material in sheet form. DIN specifications are issued by Deutscher Normenausschuss (DNA), Berlin W15, and may be obtained from:

Beuth-Vertrieb,
Köln, Friesenplatz 16.

The sub-headings 'L', 'LT' and 'ST' used on the *Static Properties* charts refer to the longitudinal, long transverse and short transverse directions respectively.

ELONGATION

The values of elongation given on the charts are quoted as the percentage elongation, at fracture, of the gauge length. For circular specimens, the gauge length is $5 d_0$, where d_0 is the diameter of the test piece measured in the gauge length. For rectangular specimens the gauge length is $5.35\sqrt{F}$, where F is the cross-sectional area of the test piece measured in the gauge length.

Details of the test pieces and method of test are described in DIN 50125.

The elongation values are measured in the longitudinal direction unless otherwise stated in the footnotes.

CASTINGS

The *Static Properties* charts give data on castings for three types of test. These are distinguished by the letters 'a', 'b' and 'c' in the row designated 'Type of Test'. The significance of these letters is indicated below.

TYPE OF TEST

'a' - This indicates that the values given are for tests on separately cast test specimens.

'b' - This indicates that the values given are the minimum properties obtained for specimens cut from production castings in areas specified by the designer.

'c' - This indicates that the values given are the average values of at least 4 specimens cut from the same casting, at thin, medium and thick sections, in areas specified by the designer.

The properties of separately cast test specimens are not normally used for design purposes, being used mainly in foundry control. However they are of interest for the

comparison of the properties of alloys, particularly between those of countries which have different methods of arriving at design values for specimens cut from castings.

It should be noted that there is often a considerable variation in mechanical properties between different areas of a casting. The properties given under 'Type of Test: b and c' are for locations specified by the designer, where particular care is taken that the feeding, rate of cooling, etc., is favourable to good properties. In other areas, over which no special precautions have been taken, the properties may not reach these values.

The separately sand cast test specimens are made and tested to the British Standard specification B.S. 2L 101. Copies of this may be obtained from:

British Standards Institution
2, Park Street,
London, W.1.
England.

The permanent mould separately cast test specimens are made and tested to the specification LN 29531. Copies may be obtained from:

Beuth-Vertrieb,
Köln,
Friesenplatz 16,
Germany.

For specimens cut from castings the specification used is either DIN 50125, obtainable from the above address or the French specification NF - A03 - 101, which may be obtained from:

l'Association Française de Normalisation (AFNOR),
23, Rue Notre Dame,
Victoires, Paris, 2^e.

FATIGUE PROPERTIES

The data given on the *Fatigue Properties* chart are based on tests made in rotating bending. A brief description of the specimens is given on the charts, and a description of the method of testing is given in DIN 50113.

The 'Nominal Maximum Stress' quoted on the charts is the stress calculated by dividing the bending moment by the section modulus. In the case of notched test bars, the section modulus is based on the core or minimum cross-section.

ELEVATED TEMPERATURE DATA

On these charts the data are presented as percentages of the appropriate values at room temperature..

Room temperature is taken to be 20°C except where otherwise stated, and the value in kg./mm²., at this temperature, on which the percentages were based, is quoted in brackets at the top of each column.

For the short time tensile tests at elevated temperatures the test pieces and methods of test are specified in DIN 50112.

For the *Properties under Load and Elevated Temperature* charts, the data are obtained from test pieces in accordance with the specifications DIN 50118 and DIN 50119.

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GENERAL PROPERTIES

GERMANY
W 3501
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Mn	Si	Zn	Fe	Al					Others	Mg
All Forms	0.05 max.	1.2 2.0	0.10 max.	0.03 max.	0.005 max.	0.05 max.					0.1 max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	gm./cm. ³	0,1	1.8				
$c^{(1)}$	cal/(gm.°C)	0,1		0.25			
λ	cal.cm/(cm. ² sec. °C)		0.34				
$\alpha^{(1)}$	per °C x 10 ⁻⁶	0,1		26.1	26.9	27.7	
ϵ							

(1) Value between 20°C and temperature indicated

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Units: kg./mm.²

Data Basis: A

STATIC PROPERTIES (SHEET 1)

GERMANY
W350I
Magnesium Alloy

Form		Sheet	
Specification		W350I	
Condition		I	
Thickness (mm.)		0.5 ≤1.0	>1.0 ≤6.0
σ_b	L	20	20
	LT		
	ST		
$\sigma_{0.2}$	L	10	10
	LT		
	ST		
(1)	L		8
	LT		
	ST		
$\sigma_{dFO.8}$ τ			
σ_L			
(1)	E	4000	
(1)	E _d	5000	
δ_b	%	12	10
Footnotes			

(1) Data Basis: C

GERMANY
W3501
Magnesium Alloy

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Data Basis: A

Units: kg./mm.²

Foot notes	Form	Extrusion and Tubing
	Specification	W350I
	Condition	0
	Thickness (mm.)	<div> <div> ≤ 2 </div> <div> > 2 ≤ 6 </div> </div>
	Cross - Sectional Area	
	σ_b	<div> <div>L</div> <div>23</div> <div>21</div> </div>
		LT
	$\sigma_{0.2}$	<div> <div>L</div> <div>17</div> <div>15</div> </div>
		LT
(1)	$\sigma_{dFO.2}$	10
		LT
	$\sigma_{dFO.5}$	
	τ	
(1)	σ_L	
(1)	E	4000
(1)	E _d	5000
	G	
	δ_a	<div> <div>2</div> <div>1.5</div> </div>
	Footnotes	<div> <div>(2)</div> <div>(3)</div> </div>

(1)	Data Basis: C	(3)	For tubing, outside diameter ≤ 125 mm.
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(2) For tubing, outside diameter ≤ 50 mm.

GERMANY
W3501
Magnesium Alloy

Units: hrs, °C, kg./mm.².

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Form	(I)	Tubing and Extrusions
Condition	I	O
t →	○ ↓	○ ↓
T ▼	Per Cent σ_B (27.5 at R.T.)	Per Cent $\sigma_{0.2}$ (16.5 at R.T.)
50	87	91
100	65	68
150	47	48
200	32	31
250	22	23
300	15	15
350	11	12

(1)	Thickness	Time.
1	1/2	1/2
2	1/2	1/2
3	1/2	1/2
4	1/2	1/2
5	1/2	1/2
6	1/2	1/2
7	1/2	1/2
8	1/2	1/2
9	1/2	1/2
10	1/2	1/2
11	1/2	1/2
12	1/2	1/2
13	1/2	1/2
14	1/2	1/2
15	1/2	1/2
16	1/2	1/2
17	1/2	1/2
18	1/2	1/2
19	1/2	1/2
20	1/2	1/2
21	1/2	1/2
22	1/2	1/2
23	1/2	1/2
24	1/2	1/2
25	1/2	1/2
26	1/2	1/2
27	1/2	1/2
28	1/2	1/2
29	1/2	1/2
30	1/2	1/2
31	1/2	1/2
32	1/2	1/2
33	1/2	1/2
34	1/2	1/2
35	1/2	1/2
36	1/2	1/2
37	1/2	1/2
38	1/2	1/2
39	1/2	1/2
40	1/2	1/2
41	1/2	1/2
42	1/2	1/2
43	1/2	1/2
44	1/2	1/2
45	1/2	1/2
46	1/2	1/2
47	1/2	1/2
48	1/2	1/2
49	1/2	1/2
50	1/2	1/2
51	1/2	1/2
52	1/2	1/2
53	1/2	1/2
54	1/2	1/2
55	1/2	1/2
56	1/2	1/2
57	1/2	1/2
58	1/2	1/2
59	1/2	1/2
60	1/2	1/2
61	1/2	1/2
62	1/2	1/2
63	1/2	1/2
64	1/2	1/2
65	1/2	1/2
66	1/2	1/2
67	1/2	1/2
68	1/2	1/2
69	1/2	1/2
70	1/2	1/2
71	1/2	1/2
72	1/2	1/2
73	1/2	1/2
74	1/2	1/2
75	1/2	1/2
76	1/2	1/2
77	1/2	1/2
78	1/2	1/2
79	1/2	1/2
80	1/2	1/2
81	1/2	1/2
82	1/2	1/2
83	1/2	1/2
84	1/2	1/2
85	1/2	1/2
86	1/2	1/2
87	1/2	1/2
88	1/2	1/2
89	1/2	1/2
90	1/2	1/2
91	1/2	1/2
92	1/2	1/2
93	1/2	1/2
94	1/2	1/2
95	1/2	1/2
96	1/2	1/2
97	1/2	1/2
98	1/2	1/2
99	1/2	1/2
100	1/2	1/2

GENERAL PROPERTIES

GERMANY
W 3504
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Mn	Si	Zn	Al						Others	Mg
Sheet	0.05 max.	0.05 0.40	0.20 max.	0.5 1.5	2.5 3.5						0.1 max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	gm./cm. ³	1, 3	1.8				
$c^{(1)}$	cal./(gm.°C)	1, 3		0.25			
λ	cal.cm/(cm. ² sec. °C)		0.25				
$\alpha^{(1)}$	per °C x 10 ⁻⁶	1, 3		26.1	27.1	27.9	
ϵ							

(1) Between 20°C and temperature indicated

Iss. No.	Date	App'd by
1	JAN. 1961	A.T.

STATIC PROPERTIES
(SHEET)

GERMANY
W3504
Magnesium Alloy

Data Basis: A

Units: kg./mm.²

Iss. No.	1	
Date	JAN. 1961	
App'd by	AT	

Form	Sheet												
Specification	W3504												
Condition	1	3											
Thickness (mm.)	20-5 ≤ 6	>6 ≤15	>15 ≤50	20-5 ≤6	>6 ≤15	>15 ≤50	20-5 ≤6	>6 ≤15	>15 ≤50	20-5 ≤6	>6 ≤15	>15 ≤50	
σ_v	L	24	23	21	27	25	23						
	LT												
	ST												
$\sigma_{c,2}$	L	14	13	10	20	18	16						
	LT												
	ST												
(1)	L	9	9	9	15	13	11						
	LT												
	ST												
$\sigma_{dFO,2}$													
$\sigma_{dFO,5}$													
τ													
σ_L													
(1)	E	4100				4200							
(1)	E _d	5200				5300							
	G												
	G _s	14	12	8	4	5	5						
Footnotes													

(1) Data Basis: C

GENERAL PROPERTIES

GERMANY
W 3510
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Mn	Si	Zn	Al						Others	Mg
Tubing and extrusions	0.1 max.	0.05 0.4	0.2 max.	0.5 1.5	5.5 6.5						0.1 max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
γ	gm./cm. ³	0	1.8				
$c^{(1)}$	cal./(gm.°C)			0.24			
λ	cal.cm./cm. ² sec. °C		0.195				
$\alpha^{(1)}$	per °C x 10 ⁻⁶	0		26.0	27.3	28.0	
ϵ							

(1) Between 20°C and temperature indicated

Iss. No.	Date	App'd by
1	Jan. 1961	AT

Iss. No.	1	
Date	Jan. 1961	
App'd by	A.T.	

Units: kg./mm.² Data Basis: A

STATIC PROPERTIES (SHEET 1)

GERMANY
W3510
Magnesium Alloy

Footnotes	Form	Tubing	Extruded shapes	
	Specification	W3510		
	Condition	O		
	Thickness (mm.)	≤ 2 > 2 ≤ 6 > 6	≤ 2 > 2 ≤ 6 > 6	
	Cross-Sectional Area			
	σ_b	L 28 T 28	28 28	
	$\sigma_{0.2}$	L 18 T 18	18 18	
(1)	$\sigma_{400.2}$	L T		13
	$\sigma_{400.3}$			
	σ_L			
(1)	E	4200		
(1)	E ₄	5200		
	G			
	δ_s	11 10 11 10		
	Footnotes	(2) (3)		

(3) Outside diameter ≤ 125mm.

(1) Data Basis: C

(2) Outside diameter ≤ 50mm.

GERMANY
W 3510
Magnesium Alloy

Data Basis: C

Units: hrs., °C, kg./mm.²

Iss. No.	1		
Date	Jan 1961		
App'd by	AT		

Form	Tubing and Extrusions
Condition	O
t →	<div style="display: flex; justify-content: space-around;"> O . t O . t </div>
T ↓	<div style="display: flex; justify-content: space-between;"> <div>Per Cent σ_B (31 at R.T.)</div> <div>Per Cent $\sigma_{0.2}$ (22 at R.T.)</div> </div>
50	98 94
100	94 83
150	73 64
200	52 41
250	33 23
300	22 8
350	10

GENERAL PROPERTIES

GERMANY
W3515
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Mn	Si	Zn	Al						Others	Mg
All Forms	0.1 max.	0.05 max. 0.40	0.2 max.	0.5 max. 2.0	6.5 max. 8.0						0.1 max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	gm./cm. ³	0, 7	1.8				
$c^{(1)}$	cal./(gm.°C)	0, 7		0.24			
λ	cal.cm/(cm. ² sec. °C)		0.9				
$\alpha^{(1)}$	per °C x 10 ⁻⁶	0, 7		26.3	27.1	27.6	
ϵ							

(1) Values between 20°C and temperature indicated

Iss. No.	1	
Date	JAN. 1961	
App'd by	A.T.	

STATIC PROPERTIES
(SHEET)

GERMANY
W 3515
Magnesium Alloy

Data Basis: A

Units: kg./mm²

Iss. No.	1	
Date	JAN. 1961	
App'd by	A.T.	

Footnotes	Form	Drawn Bar	Extruded Bar	Die Forgings	
	Specification	W 3515			
	Condition	0			7
	Thickness				
	Cross-Sectional Area (mm ²)	≤1000	5000-12,300	>10000-50000	
	σ _B	L 28 T	30 28 32 32	24 28	
	σ _{0.2}	L 20 T	21 20 23 23	16	
(1)	σ _{4FO,2}	L 14 T	14 12 15 15		
	σ _{4FO,5}				
	σ _L				
(1)	E	4,500			
(1)	E	5,500			
(2)	G	10 - 10	38 36 36 3		
	Footnotes				

- (1) Data Basis: C
(2) The two values refer to longitudinal and transverse directions of testing respectively

GERMANY
W3515
Magnesium Alloy

Units: hrs, °C, kg./mm.²

Iss. No.	1		
Date	JAN. 1961		
App'd by	A.T.		

[illegible]

GENERAL PROPERTIES

GERMANY
3.5104
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Mn	Si	Fe	Ni	Cr	Zr	Cl				Mg
Casting	3.6 5.5	0.15 max.	0.01 max.	0.01 max.	0.005 max.	0.03 max.	0.4 1.0	0.01 max.				Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200		
γ	gm./cm. ³		1.81				
$c^{(1)}$	cal./(gm.°C)			0.23			
λ	cal.cm./(cm. ² sec. °C)		0.27				
$\alpha^{(1)}$	per °C x 10 ⁻⁶				27.3		

(1) Between 20°C and temperature indicated.

Iss. No.	Date	App'd by
1	Jan. 1961	A.T.

GENERAL PROPERTIES

GERMANY
3.5114
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Mn	Si	Fe	Ni	Cr	Zr	Th	Cl			Mg
Casting	4.8 6.3	0.15 max.	0.01 max.	0.01 max.	0.003 max.	0.03 max.	0.4 1.0	1.5 2.0	0.01 max.			Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200		
γ	gm./cm. ³		1.87				
$c^{(1)}$	cal./(gm.°C)			0.23			
λ	cal.cm./(cm. ² sec. °C)		0.27				
$\alpha^{(1)}$	per °C x 10 ⁻⁶				27.1		

(1) Between 20°C and temperature indicated.

Iss. No.	Date	App'd by
1	JAN. 1961	A.T.

Iss. No.	1	
Date	MAR '62	
App'd by	AT	

Data Basis: A

Units: kg./mm.²

STATIC PROPERTIES (SHEET)

GERMANY
3.5114
Magnesium Alloy

Notes	Form	Sand Casting																	
	Specification	3.5114																	
	Condition	9																	
	Thickness																		
	Gross - Sectional Area																		
	Type of Test	a	b	c															
	σ_B	25	19	22															
	$\sigma_{0.2}$	15	11	12															
	$\sigma_{dFO,2}$	12	10	11															
	$\sigma_{dFO,5}$																		
(1)	τ	14	14	14															
	σ_L																		
(1)	E	4,400																	
(1)	E _d	4,400																	
	G																		
	σ_s																		
	Footnotes		4	2	3														

(1) Data Basis: C

GENERAL PROPERTIES

GERMANY
3-5194
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu						Others	Mg
Casting	8.3 10.0	0.3 1.0	0.15 0.3	0.3 max.	0.2 max.						0.2 max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	gm./cm. ³	2, 6, 8	1.8				
$c^{(1)}$	cal./(gm.°C)			0.24			
λ	cal.cm./(cm. ² sec. °C)	2, 6, 8	0.19				
$\alpha^{(1)}$	per °C x 10 ⁻⁶	2		26.0	27.0	27.8	
ϵ							

(1) Between 20°C and temperature indicated

Iss. No.	1	7/11/1961	A.T.
Date			
App'd by			

Iss. No.	1	
Date	MAR '62	
App'd by	A.T.	

Units: kg./mm.²

Data Basis: A

STATIC PROPERTIES (SHEET)

GERMANY
3-5194
Magnesium Alloy

Form	Sand Casting		Permanent Mould Casting		Pressure Die Casting	
Specification			3-5194			
Condition	2		6		8	
Thickness						
Cross-Sectional Area						
Type of Test	a	b	a	b	a	b
σ_B	24	17	24	17	22	
$\sigma_{0.2}$	11	9	11	9	15	
$\sigma_{dFO.2}$	10	8	10	8	10	
$\sigma_{dFO.5}$						
τ	12	10	12	10		
σ_L						
(1)	4,400					
E						
(1)	4,400					
E _d						
(1)	1,760					
G						
(1)	6		3		0.5	
σ_s						
Footnotes						

(1) Data Basis: C

GERMANY
3-5194
Magnesium Alloy

GERMANY
3-5194
Magnesium Alloy

Iss. No.	1		
Date	JAN. 1951		
App'd by	A.T.		

Units: kg./mm.² Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles							
					Nominal Maximum Stress				10 x 10			
	Rotating Bending	Separately sandcast specimens Unnotched	2 , 6	- 1.0					8.0			
		Separately sandcast specimens. Notched, radius=120mm K=2.0								7.0		
	Footnotes											

GERMANY
3-5194
Magnesium Alloy

Units: kg./mm.².

Iss. No.	1		
Date	JAN 1961		
App'd by	AT		

[illegible]

GENERAL PROPERTIES

GERMANY
3-6104
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Mn	Si	Fe	Ni	Cu	Zr	Rare Earths	Cl				Mg
Casting	3.5 5.0	0.15 max.	0.01 max.	0.01 max.	0.005 max.	0.03 max.	0.4 1.0	0.75 1.75	0.01 max.				Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	gm./cm. ³	I	1.8				
c ⁽¹⁾	cal./(gm.°C)			0.23			
λ	cal.cm/(cm. ² sec. °C)		0.27				
α ⁽¹⁾	per °C x 10 ⁻⁶	I		26.0	27.0	27.8	
ϵ							

(1) Between 20°C and temperature indicated

Iss. No.	1		
Date	JAN. 1961		
App'd by	A.T.		

Iss. No	1		
Date	MAR '52		
App'd by	A.T.		

Units: kg./mm.²

Data Basis: A

STATIC PROPERTIES (SHEET)

GERMANY
3-6104
Magnesium Alloy

Footnotes	Form	Sand Casting																		
	Specification	3-6104																		
	Condition	I																		
	Thickness																			
	Cross - Sectional Area																			
	Type of Test	a	b	c																
	σ_B	21	19																	
	$\sigma_{0.2}$	15	14																	
(1)	$\sigma_{dF0.2}$	14	13																	
	$\sigma_{dF0.5}$																			
(1)	τ	10	9																	
	σ_L																			
(1)	E	4400																		
(1)	E _d	5500																		
	G																			
	G _s	3	2.0																	
	Footnotes																			

(1) Data Basis: C

GERMANY
3-6104
Magnesium Alloy

GERMANY
3-6104
Magnesium Alloy

Units: kg./mm².

Iss. No.	1		
Date	20.10.61		
App'd by	A.T.		

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles															
					Nominal		Maximum Stress													
							5 x 10 ⁴													
	Rotating Bending	Separately sandcast specimens Unnotched	I	- 1.0				2-6												
		Separately sandcast specimens. Notched, radius=120mm K=2.0	I	- 1.0					7.0											
Footnotes																				

GERMANY
3-6104
Magnesium Alloy

Units: hrs, °C, kg./mm.²

Iss. No.	1		
Date	JAN. 1961		
App'd by	A.T.		

[illegible]

GENERAL PROPERTIES

GERMANY
3-6204
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Mn	Si	Fe	Ni	Cu	Zr	Rare Earths					Mg
Casting	0.8 3.0	0.15 max.	0.01 max.	0.01 max.	0.005 max.	0.03 max.	0.4 1.0	2.5 4.0					Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	gm./cm. ³	I	1.8				
$c^{(1)}$	cal./gm.°C			0.25			
λ	cal.cm./cm. ² sec. °C		0.24				
$\alpha^{(1)}$	per °C x 10 ⁻⁶	I			27.6		
ϵ							

(1) Between 20°C and temperature indicated

Iss. No.	1	
Date	JAN. 1961	
App'd by	A.T.	

Iss. No	1		
Date	MAR '52		
App'd by	A.T.		

Units: kg./mm.²

Data Basis: A

Footnotes	Form	Sand Casting																	
	Specification	3-6204																	
	Condition	I																	
	Thickness																		
	Cross-Sectional Area																		
	Type of Test	a	b	c															
	σ_B	14	12																
	$\sigma_{0.2}$	10	9																
	$\sigma_{dFO.2}$	9	8																
	$\sigma_{dFO.5}$																		
	τ																		
	σ_L																		
(1)	E	4400																	
(1)	E ₄	5500																	
	G																		
	δ_5		3	2															
	Footnotes																		

(1) Data Basis: C

STATIC PROPERTIES
(SHEET)

GERMANY
3-6204
Magnesium Alloy

Iss. No.	1		
Date	JAN, 1961		
App'd by	A.T.		

Units: kg./mm.²

Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles																
							5 x 10 ⁴														
					Nominal Maximum Stress																
	Rotating Bending	Separately sandcast specimens Unnotched	1	- 1.0			6.7														
		Separately sandcast specimens, Notch radius 1.20 mm. K _t 2.0	1	- 1.0				5.1													
	Footnotes																				

FATIGUE PROPERTIES

GERMANY
3.6204
Magnesium Alloy

**SHORT TIME PROPERTIES
AT ELEVATED TEMPERATURE**
(SHEET)

GERMANY
3-6204
Magnesium Alloy

Data Basis: C

Units: hrs., °C., kg./mm.

Ins. No.	I	
Date	FEB '52	
App'd by	A.T.	

Form	Separately Sand Cast Test Specimens											
Condition	I						O					
t →	Per Cent (15 at R.T.)	O. ↓	Per Cent (9 at R.T.)	O. ↓	Per Cent (16 at R.T.)	O. ↓	Per Cent (9 at R.T.)	O. ↓	Per Cent (16 at R.T.)	O. ↓	Per Cent (9-5 at R.T.)	O. ↓
50	100		97		99		94		94			
100	98		94		94		86		86			
150	96		86		87		81		81			
200	89		83		78		76		76			
250	79		72		66		65		65			
260	65		56									
300	57		61		51		48		48			
350					34		29		29			

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET)

GERMANY
3-6204
Magnesium Alloy

Units: hrs, °C

Data Basis: A

CREEP DATA

Form		Separately Sand Cast Test Specimens													
Condition		I													
t →		10	30	100	250	300	500	800	1000						
T ↓	Total Strain Per Cent	Per Cent σ_B ($\sigma_B = 14 \text{ Kg/mm}^2$ at room temperature) ⁽¹⁾													
200	0.05	40		31			26		25						
	0.10	51		44			33		31						
	0.20					46			38						
250	0.05	23		16											
	0.10	23		17			15								
	0.20		23	21		18		14	13						
	0.50			23			21		19						
	0.75				23			21	20						
	1.00					23		21	21						

(1) Data Basis A

Iss. No.	1	
Date	JAN 1961	
App'd by	A.T.	

GENERAL PROPERTIES

GERMANY
3-6254
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Mn	Si	Fe	Ni	Cu	Cl	Zr	Th			Mg
Casting	1.7 2.7	0.15 max.	0.01 max.	0.01 max.	0.005 max.	0.03 max.	0.01 max.	0.4 1.0	2.7 3.3			Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	gm./cm. ³	I	1.8				
$c^{(1)}$	cal./ (gm.°C)	I		0.23			
λ	cal.cm./ (cm. ² sec. °C)	I	0.25				
$\alpha^{(1)}$	per °C x 10 ⁻⁶	I		26.0	27.0	27.8	
ϵ							

(1) Between 20°C and temperature indicated

Iss. No.	1	
Date	JAN. 1961	
App'd by	A.Z.	

Iss. No	1		
Date	MAR '62		
App'd by	A.T.		

Units: kg./mm.²

Data Basis: A

STATIC PROPERTIES (SHEET)

GERMANY
3-6254
Magnesium Alloy

Foot notes		Form	Sand Casting																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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(1) Data Basis: C

GERMANY
3-6254
Magnesium Alloy

3.6254

Magnesium Alloy

Units: kg./mm.²

Iss. No.	1		
Date	JAN. 1961		
App'd by	A.T.		

[illegible]

Iss. No.	1	
Date	FEB 62	
App'd by	AT	

Units: hrs., °C., kg./mm.

Data Basis: C

SHORT TIME PROPERTIES
AT ELEVATED TEMPERATURE
(SHEET)

GERMANY
3-6254
Magnesium Alloy

Form	Separately Sand Cast Test Specimens									
Condition	I									
t →	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
T ↓	Per Cent (19 at 0°C)	Per Cent (9 at 0°C)	Per Cent E (4400 at 0°C)							
50	100	100	100							
100	95	100	95							
150	66	89	93							
200	58	78	91							
250	53	67								
300	42	56								
325	32	50								
350 (1)	32	53								

(1) Data Basis: A. For specimens cut from castings, Per Cent $\sigma_B = 22$, Per Cent $\sigma_{0.2} = 42$

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET)

GERMANY
3-6254
Magnesium Alloy

Units: hrs, °C

Data Basis: A

CREEP DATA

Form		Separately Sand Cast Test Specimens															
Condition		I															
$t \rightarrow$		1	2	3	8	10	30	55	100	1000							
T ↓	Total Strain Per Cent	Per Cent σ_s ($\sigma_s = 19 \text{ Kg/mm}^2$ ⁽¹⁾ at room temperature)															
300	0.05		21		17												
	0.1					22			14								
	0.2					25			18								
	0.5					29			24	18							
	0.75						28		26	19							
	1.0							29	27	20							
350	0.05		11		9.5	8.4			5.8								
	0.1	17				12			8.4								
	0.2			17		15			8.4	6.8							
	0.5					17			11	7.4							
	0.75						17		12	7.9							
	1.0						15		13	9.0							

(1) Data Basis: A

Iss. No.	1		
Date	JAN. 1961		
App'd by	A.T.		

ITALIAN SECTION

Volume III
Magnesium,
Nickel &
Titanium Alloys

ITALIAN SECTION

A range of magnesium alloys is produced in Italy for use in aircraft construction. For the most part these alloys are ordered to United Kingdom or United States specifications, and the Italian alloys are, for practical purposes, identical with the equivalent United Kingdom or U.S. alloys.

For this reason it is not proposed in this Handbook to present separate charts giving the properties of the Italian alloys, but instead the user is referred to the data presented in the United Kingdom and United States sections.

The table below gives the designations of the Italian magnesium alloys used structurally in aircraft and the corresponding United Kingdom or United States designation.

AZ 31 B	U.S. specification	Wrought Alloy
AZ 80 A	U.S. specification	Wrought Alloy
ZK 60 A	U.S. specification	Wrought Alloy
El A 9	to U.K. specification 2L 121	Casting Alloy
El A 9V	to U.K. specification 2L 122	Casting Alloy
Z5Z	to U.K. specification L 127	Casting Alloy

NICKEL AND TITANIUM

No nickel or titanium alloys are produced in Italy for aeronautical applications.

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NETHERLANDS SECTION

In the Netherlands a number of magnesium alloys is produced for use in aircraft construction. These are all casting alloys. They are produced in close agreement with United States or United Kingdom Specifications.

As typical examples, the following designations can be mentioned.

UNITED KINGDOM DESIGNATIONS

ZL 121,	ZL 122
L 127,	DTD 711A
L 128,	DTD 748

UNITED STATES DESIGNATIONS

AZ 63 A
AZ 91 C
AZ 92 A

Reference should be made to the appropriate charts in the United Kingdom and United States sections for the properties of these alloys.

Volume III
Magnesium
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UNITED KINGDOM SECTION

CONTENTS

1. Introductory Notes
2. Charts as given in the table below.

<i>Magnesium Alloy</i>	<i>Title of Chart</i>	<i>Issue No.</i>	<i>Date</i>
D.T.D. 118A	General Properties	1	Feb. 1962
D.T.D. 142A	Static Properties, Sheet 1	1	"
	Static Properties, Sheet 2	1	"
D.T.D. 259A	General Properties	1	"
	Static Properties	1	Aug. 1962
D.T.D. 742	General Properties	1	Feb. 1962
	Static Properties	1	"
D.T.D. 622A	General Properties	1	"
D.T.D. 626A	Static Properties, Sheet 1	1	"
	Static Properties, Sheet 2	1	"
2L. 121	General Properties	2	Jan. 1963
2L. 122	Static Properties	1	Aug. 1962
	Fatigue Properties	1	Feb. 1963
	Short Time Properties at Elevated Temperature	1	"
L. 127	General Properties	2	Jan. 1963
D.T.D. 711A	Static Properties	2	"
	Fatigue Properties	1	Feb. 1963
	Short Time Properties at Elevated Temperature	1	"
L. 128	General Properties	1	"
D.T.D. 748	Static Properties	1	Aug. 1962
<i>Nickel Alloy</i>			
D.T.D. 10B	General Properties	1	Feb. 1963
D.T.D. 192	Static Properties, Sheet 1	1	"
D.T.D. 196	Static Properties, Sheet 2	2	"
D.T.D. 200A	Short Time Properties at Elevated Temperature	1	Aug. 1962
	Properties under Load and Elevated Temperature	1	"

<i>Nickel Alloy</i>	<i>Title of Chart</i>	<i>Issue No.</i>	<i>Date</i>
D.T.D. 703B	General Properties	2	Jan. 1963
	Static Properties, Sheet 1	2	"
	Static Properties, Sheet 2	1	Aug. 1962
	Fatigue Properties	1	"
	Short Time Properties at Elevated Temperature	2	Jan. 1963
	Properties under Load and Elevated Temperature	1	Feb. 1963
<i>Titanium Alloy</i>			
D.T.D. 5003A	General Properties	1	Feb. 1962
D.T.D. 5013A	Static Properties, Sheet 1	1	"
D.T.D. 5023A	Static Properties, Sheet 2	1	"
D.T.D. 5033A	Fatigue Properties	1	Feb. 1963
D.T.D. 5063			
D.T.D. 5073			
D.T.D. 5053	General Properties	1	"
D.T.D. 5143	Static Properties	1	"
	Short Time Properties at Elevated Temperature	1	Aug. 1962
	Properties under Load and Elevated Temperature	1	Feb. 1963
D.T.D. 5083	General Properties	1	"
D.T.D. 5093	Static Properties, Sheet 1	1	"
	Static Properties, Sheet 2	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature		
	Sheet 1	1	"
	Properties under Load and Elevated Temperature		
	Sheet 2	1	"

Volume III
Magnesium
Nickel and
Titanium Alloys

UNITED KINGDOM SECTION

INTRODUCTORY NOTES

The *Introduction to Volume III* of this Handbook explains the general layout adopted for the presentation of the data, together with details of the properties considered and the explanation of various terms. The purpose of the following notes is to amplify these points, where necessary, in relation to those United Kingdom alloys which are included.

DESIGNATIONS AND SPECIFICATIONS

In the United Kingdom, magnesium, nickel and titanium alloys for aircraft use are supplied either to British Standard specifications (in which case the number is prefixed by the letter 'L'), or to D.T.D. specifications which are issued by the Directorate of Materials Research and Development of the Ministry of Aviation.

'D.T.D.' specifications are issued either to meet a limited requirement not covered by any existing British Standard Specification or to serve as a basis for inspection of materials the properties and uses of which are not sufficiently developed to warrant submission to the British Standards Institution for standardisation. 'D.T.D.' specifications may later be replaced by British Standard Specifications.

Copies of British Standard Specification may be obtained from:

British Standards Institution,
2, Park Street,
London, W.1.

'D.T.D.' specifications are published by Her Majesty's Stationery Office and copies may be obtained from:

H.M. Stationery Office,
York House,
Kingsway, London, W.C.2.

ALLOYS COVERED

This Section of the Handbook lists the available established data on seven groups of magnesium alloys, three groups of titanium alloys and two groups of nickel alloys. Each group consists of alloys having basically the same chemical composition, and each specification within a group refers to a particular form and condition of the material.

These alloys are those most widely used structurally in aircraft, neglecting nickel and titanium alloys used solely for castings or for rivets. A large proportion of magnesium is used in the cast form and for this reason magnesium casting alloys have been included.

The designations of the materials covered, together with the forms in which they are produced are listed below:

MAGNESIUM ALLOYS

D.T.D. 118A	-	Sheet and strip
D.T.D. 142A	-	Bar and extrusions
D.T.D. 259A	-	Bar and extrusions
D.T.D. 522A	-	Bar and extrusions
D.T.D. 626A	-	Sheet and strip
D.T.D. 742	-	Sheet and strip
2L. 121	}	- Sand and chill castings
2L. 122		
L. 127	}	- Sand and chill castings
D.T.D. 711A		

NICKEL ALLOYS

D.T.D. 10B	-	Sheet
D.T.D. 192	-	Bar, stampings and forgings
D.T.D. 196	-	Bar - suitable for cold bending
D.T.D. 200A	-	Bar
D.T.D. 703B	-	Sheet and strip
	-	Bar

TITANIUM ALLOYS

D.T.D. 5003A, 5013A	-	Bar and billet - suitable for welding
D.T.D. 5023A, 5033A	-	Sheet and strip - suitable for welding
D.T.D. 5063	-	Tubes - suitable for pipe tubes and high pressure hydraulic systems where flaring is required
D.T.D. 5073	-	
D.T.D. 5053	-	Bar and billets
D.T.D. 5143	-	Forgings
D.T.D. 5083	-	Bar and billets
D.T.D. 5093	-	Sheet

Although there is no official specification for bar material of the composition of D.T.D. 703B, the properties are given in this section as the material is widely used.

CHEMICAL COMPOSITION

The *General Properties* charts give the chemical composition by quoting the limits of the alloying elements as a percentage by weight of the total. In the case of magnesium alloys containing zirconium the percentage of 'available' zirconium is given, i.e. that portion of the zirconium which is soluble in dilute hydrochloric acid.

CONDITION

The 'Condition' row on the charts refers to the type of heat treatment and conditioning. Although there are no officially recognised symbols to describe the various conditions, for simplicity the following designations are used in this Section:

MAGNESIUM ALLOYS

- M - As manufactured, i.e. as rolled, extruded or cast. This may also include annealing or stress relieving by the supplier
- O - Softened
- $\frac{1}{2}$ H - $\frac{1}{2}$ Hard, cold rolled
- P - Precipitation treated
- W - Solution treated

NICKEL ALLOYS

- A - Annealed
- C.D.A. - Cold drawn and annealed or cold rolled and annealed
- H.D. - Hard drawn (rolled and tempered, or rolled, drawn and tempered)
- H.R. - Hot rolled or hot forged

TITANIUM ALLOYS

- A - Annealed
- H.T. - Heat treated

For details of the times and temperatures of heat treatments reference should be made to the relevant material specification.

NOTATION

The notation used in this Section of the Handbook for the various physical and mechanical properties of the United Kingdom alloys is defined on the *Notation* chart in the *Introduction to Volume III*. This chart also compares the notation used for other National Sections. Points where any amplification is needed are dealt with under the appropriate headings below.

UNITS

The units used for the various parameters and properties are indicated on each of the charts. For mechanical properties the stresses and moduli are given in units of 10^3 lb/in.² whilst temperature is quoted in degrees Centigrade. For conversion to metric units see the *Conversion Scales* chart given in the *Introduction to Volume III*.

DATA BASIS

The *Introduction to Volume III* of this Handbook describes the use of symbols 'A', 'B' and 'C' denoting the data basis of the values for the various properties given on the charts. Special aspects of this in relation to the values quoted for the United Kingdom alloys are outlined below:

- A - This indicates that the values listed are the minimum to be expected for the given material. The only values considered 'guaranteed minimum' are those for f_t and in most cases t_1 and e , which are marked as Data Basis 'A' and which are quoted for the grain directions stated in the relevant specification. The remaining values marked as data basis 'A' are 'derived' values; that is, tests indicate that a material just meeting the specification requirements for f_t , t_1 and e would have compressive, shear and bearing strength equal to the values quoted. Both minimum and maximum values of f_t are specified for commercially pure titanium which is available in different grades to comply with forming requirements.
- B - This data basis is not used in the United Kingdom charts.
- C - This indicates that the values listed are typical for the material, there being insufficient data to determine values for basis 'A' or 'B'.

In general the data basis used on any chart is shown at the top of the chart but special attention must be paid to the footnotes which sometimes indicate a different data basis for some particular part of the chart.

STATIC PROPERTIES CHART

Tensile and Compressive Strengths

In the United Kingdom, official specifications generally quote the 0.1 per cent proof stress in tension, t_1 and thus this value is given on the charts. It should be noted that in other National Sections the 0.2 per cent proof stress (or offset yield stress) in tension is given.

The sub-headings 'L' , 'LT' and 'ST' used with the tensile and compressive strengths on the *Static Properties* Charts refer to the longitudinal, long transverse and short transverse directions respectively.

The tensile properties are obtained from test pieces selected in accordance with the appropriate clauses of the relevant material specifications.

STRAIN RATE

The tensile strength of titanium is dependent to a marked extent on the strain rate. The values of f_t and t_1 given on the *Static Properties* charts apply to a strain rate of 0.002 to 0.005 in./in./min. up to the 0.5 per cent proof stress, with stops for readings not longer than 1 second and a total stopped time not greater than 20 seconds. Beyond the 0.5 per cent proof stress the strain rate is between 0.15 and 0.3 in./in./min. Fuller details of the testing procedure to achieve these strain rates are given in Appendices to the relevant material specifications.

SHEAR STRENGTH

The torsional ultimate stress f_q , is defined as the stress corresponding to the maximum torque that the member will sustain, irrespective of whether failure is by plastic shear, buckling of the wall, or a combination of both. The values given on the charts were obtained from torsion tests on tubes and solid section bars, and were determined on the assumption that the stress at any section was directly proportional to the distance from the axis of the tube or bar. Where values of f_q are given for material in forms other than tube, the tests were carried out on tubes or solid circular bars machined from the form in question. The tests were made on specimens with a length/diameter ratio of about 15 for tube materials and 8 for bar materials.

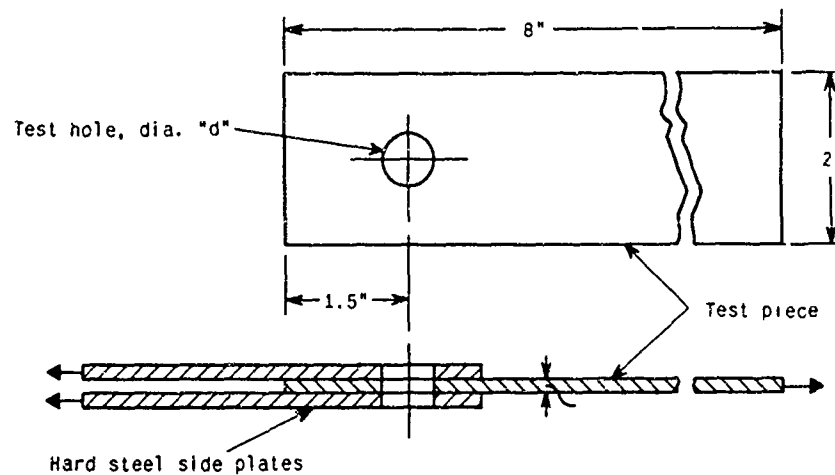
Values of f_q are given for a range of values of the ratio D/t , where D and t are the external diameter and the wall thickness respectively of the torsion member. Values of D/t of 2, 5 and 10 have been taken for wrought alloys and 11 for cast alloys.

The parameter D/t is included on the appropriate *Static Properties* Charts in the United Kingdom section by the alteration of the row used for 'Cross-sectional Area' in the other National Sections.

BEARING STRENGTH

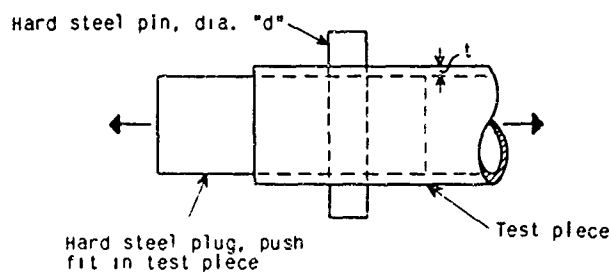
The symbol b_{10} denotes the 1.0 per cent proof stress in bearing. The values are derived from a series of tests of single bolt joints in plates and tubes, covering the effects of clearances, lateral support (such as that given by bolt heads or adjacent plates), curvature of the bearing surfaces and ratio of pin-diameter to plate thickness. b_{10} is defined as that stress which will produce a permanent deformation of the hole equal to 1.0 per cent of its original diameter.

The dimensions of the test specimens are indicated in Figures 1 and 2.



Note:- d/t in tests on wrought alloys was between 3.3 and 4.5. For cast magnesium alloys d/t was between 0.74 and 1.25 and the specimens were 5" diameter flanges machined from flanged cylinders of 1.85" internal dia. with test holes reamed to size on a 3.4" concentric circle, loaded diametrically

Fig.1 Lug Type Tests for Sheet and Plate Materials



Note:- d/t in tests was approximately constant at 5.0

Fig.2 Plug Type Tests for Bar and Tube Materials

ELASTIC AND SHEAR MODULI

The sub-headings 'L' and 'T' used with the elastic moduli on the *Static Properties* charts refer to the longitudinal and transverse directions respectively. Throughout the charts the values quoted for moduli should be regarded as typical, that is, data basis 'C'. This has been emphasised where the data are from unofficial sources by a footnote on the chart.

ELONGATION

The values of elongation given on the charts are quoted as the percentage elongation after failure for specimens as defined in the appropriate clause of the material specification. The specimens have a gauge length of four times the square root of the cross-sectional area or in some instances 2 inches.

FORGINGS

The strength properties of forgings can vary markedly, but the values quoted give an indication of the level of strength that might be expected in a simple forging. For more complex forgings the strength may be less. Due consideration should also be given to the effects of grain direction. For more precise strength values, tests should be made on the complete forging.

STATIC PROPERTIES CHARTS: CAST MAGNESIUM ALLOYS

Strength properties of magnesium castings are given for two Types of Test as explained below.

TYPE OF TEST: a

The strength properties of aeroplane casting materials are controlled by specifying a minimum strength that must be attained by test bars cast from the same batch of material and under the same conditions as the actual castings. These test bars are made and tested in accordance with British Standard 2L.101. The minimum strength values for such test bars are quoted on the *Static Properties* charts in the columns headed 'Type of Test: a'. The data basis is 'A', i.e. the minimum to be expected for the given material.

TYPE OF TEST: c

In general the strength properties in various parts of castings and in different castings differ from those of the standard test bars. To avoid excess weight incurred in allowing a sufficient margin of safety when designing by calculation based on 'Type of Test: a' strength values it is usual to base the acceptance of important castings on strength tests made on the actual castings. The strength values given on the *Static Properties* charts under 'Type of Test: c' are used as a guide in designing castings for approval by test. The 'Type of Test: c' values are estimates of the mean strength of all material made to the given specification, and have been obtained from cut-up tests on specimens taken from test castings of a standardised design, cast by two or three foundries. It should be noted that the geometries of the specimens used to determine the static properties are not of the same form as those used for wrought alloys. The values indicate the general level of strength that can be obtained in castings of this type, but higher or lower mean strengths may occur in individual batches and other designs of castings. The data basis is 'C'.

FATIGUE PROPERTIES

The data, given on the *Fatigue Properties* charts cover tests in rotating bending and reversed flexural and repeated axial loading. A brief description of the various specimens tested is given on the charts.

Rotating bending tests were in general carried out on a Wohler type machine. The smooth specimens were round bars 0.30 - 0.40 inches diameter. The values of the elastic stress concentrations factor K_t for the notched specimens varied from 2.0 to 4.0

The reversed flexural tests were made on N.P.L./Bristol combined stress machines with a stress ratio of -1.0 using standard hollow specimens both smooth and with 0.04 inch radius fillet.

In all cases the 'Nominal Maximum Stress' quoted on the charts is the maximum stress across the critical section of the specimen determined at the maximum load of the fatigue cycle, without correction for stress concentration effects. The 'Stress Ratio' quoted on the charts is the ratio of minimum to maximum stress during the fatigue cycle with compressive stress being taken negative and tensile stress positive.

It should be noted that there is always a wide scatter of results with tests of this type and the values given on the charts represent mean lines through the scatter bands.

On the United Kingdom *Fatigue Properties* charts, the column headed 'Form and Condition' gives the appropriate specification number since this defines both the form and the condition of the material. In other National Sections this column is headed simply 'Condition'.

ELEVATED TEMPERATURE DATA

On these charts the data are presented as percentages of the appropriate room temperature value. The appropriate room temperature value of the specimens tested is indicated when known at the head of the column. It is not possible to give precise details of the test specimens used in determining the elevated temperature properties, since the test method has not been standardised.

No data are available for the Recovered Properties after Exposure to Elevated Temperature but it is known that for the Nickel and Titanium alloys included the room temperature properties are not greatly affected by exposure to temperature in the normal working range.

On the *Properties under Load and Elevated Temperature* charts, creep data are presented which give the stress (expressed as a percentage of the room temperature value of f_t) which, for a given time and at a given temperature, will produce given values of total deformation or failure. It should be noted that the 'total deformation' is the total plastic strain and includes neither the initial (or elastic) strain nor the thermal expansion.

February 1963.

GENERAL PROPERTIES

U.K.
D.T.D.118A,142A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Cu	Si	Fe	Ni	Ca	Mn					Mg
All Forms	0.05 Max.	0.03 Max.	0.02 Max.	0.02 Max.	0.03 Max.	0.005 Max.	0.02 Max.	1.0 2.0					Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.74				
$c^{(1)}$	cal./(gm.°C)			0.24			
k	cal.cm./(cm. ² sec. °C)			0.34			
$\alpha^{(1)}$	per °C x 10 ⁻⁶				27		
ϵ							

(1) Between 20°C and temperature indicated.

Iss. No.	1		
Date	Feb '62		
App'd by	A.T.		

Iss. No.	1	
Date	FEB '62	
App'd by	A.T.	

Units: 10^3 lb./in.^2

Data Basis: A

STATIC PROPERTIES (SHEET 1)

U.K.
D.T.D. 118A, 142A
Magnesium Alloy

Form	Sheet
Specification	D.T.D. 118 A
Condition	M, O
Thickness (in.)	
f_1	L 29.1 LT ST
t_1	L 8.9 LT ST
C_1	L
C_2	L LT ST
C_5	L
f_a	
f_b	
b_{10}	
E	6,500
E_c	
G	
e	% 5
Footnotes	

(1) Thickness > 0.104 in

STATIC PROPERTIES
(SHEET 2)

U.K.
D.T.D. 118A, 142A
Magnesium Alloy

Data Basis: A

Units: 10^3 lb./in.^2

Iss. No	1	
Date	FEB '52	
App'd by	A.T.	

Form	Bars and Extrusions
Specification	D.T.D. 142 A
Condition	M
Thickness (in.)	
Gross - Sectional Area (in. ²)	
f_t	L 33.6
f_t	T
f_t	L 17.9
f_t	T
C_1	L
C_2	L
C_3	T
f_s	
f_b	
b_{10}	
E	6,450
E_c	
G	
e	% 4
Footnotes	

GENERAL PROPERTIES

U.K.
D.T.D. 259A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Cu	Si	Fe	Ni						Mg
Bars and Extrusions	5.5 8.5	1.5 Max.	0.20 0.40	0.1 Max.	0.1 Max.	0.03 Max.	0.005 Max.						Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.80				
$c^{(1)}$	cal./(gm.°C)			0.24			
k	cal.cm./cm. ² sec. °C)			0.20			
$\alpha^{(1)}$	per °C x 10 ⁻⁶				27		
ϵ							

(1) Between 20°C. and temperature indicated.

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Iss. No.	Date	App'd by

Iss. No	1	
Date	AUG 62	
App'd by	A.T.	

Units: 10^3 lb./in.^2 Data Basis: A

STATIC PROPERTIES (SHEET)

U.K.
D.T.D. 259A
Magnesium Alloy

Footnotes	Form	Bars and Extrusions			
	Specification	D.T.D. 259A			
	Condition	M			
	Thickness (in.)				
	D/t	2	5	10	
	f_t	L 38.1	T 38.1	38.1	
	f_t	L 24.6	T 24.6	24.6	
	C_1	L			
	C_2	L			
	C_3	L			
	f_q	27.6	24.8	21.6	
	f_b				
	b_{10}	32.5	32.5	32.5	
	E	6,500			
	E_c				
	G	2,400			
	e	% 10	10	10	
	Footnotes				

GENERAL PROPERTIES

U.K.
D.T.D. 742
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Ca	Si	Cu	Ni	Fe					Mg
Sheet	2.5 3.5	0.6 1.4	0.15 0.7	0.3 Max.	0.3 Max.	0.05 Max.	0.005 Max.	0.005 Max.					Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.77				
$c^{(1)}$	cal./(gm.°C)			0.24			
k	cal.cm./(cm. ² sec. °C)			0.23			
$\alpha^{(1)}$	per °C x 10 ⁻⁶				26		
ϵ							

(1) Between 20°C and temperature indicated.

Iss. No.	Date	App'd by
1	Feb '62	A T

Iss. No.	1	
Date	FEB '62	
App'd by	A.T.	

Units: 10^3 lb./in.^2

Data Basis: A

STATIC PROPERTIES (SHEET)

U.K.
D.T.D. 742
Magnesium Alloy

Footnotes	Form	Sheet and Strip
	Specification	D.T.D. 742
	Condition	$\frac{1}{2}$ H
	Thickness (in.)	
	f_1	L 35.8 LT ST
	t_1	L 22.4 LT ST
	C_1	L LT ST
	C_2	L LT ST
	C_3	L
	f_a	
	f_b	
	b_{10}	
	E	
	E_c	
	G	
	e	% 8
	Footnotes	

GENERAL PROPERTIES

U. K.
D.T.D.622A,626A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Zr	Mn	Cu	Al	Si	Fe	Ni					Mg
All Forms	2.5 4.0	0.5 1.0	0.15 Max.	0.03 Max.	0.02 Max.	0.01 Max.	0.01 Max.	0.005 Max.					Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.80				
$c^{(1)}$	cal./(gm.°C)			0.24			
k	cal.cm/(cm. ² sec. °C)			0.30			
$\alpha^{(1)}$	per °C x 10 ⁻⁶				27		
ϵ							

(1) Between 20°C. and temperature indicated.

1	Feb '62	A.T.
Iss. No.	Date	App'd by

U.K.
D.T.D. 622A, 626A
Magnesium Alloy

iss. No.	1		
Date	FEB '62		
App'd by	A.T.		

Units: 10^3 lb./in.²

Form	Sheet and Strip
Specification	D.T.D. 626A
Condition	M
Thickness (in.)	<div> <div> <div><</div> <div>0.048</div> <div>></div> </div> <div> <div>0.0480</div> <div>0.104</div> <div>0.104</div> </div> </div>
f_1	<div> <div>L</div> <div>35.8</div> <div>38.1</div> <div>38.1</div> </div>
t_1	<div> <div>LT</div> <div></div> <div></div> <div></div> </div>
C_1	<div> <div>ST</div> <div></div> <div></div> <div></div> </div>
C_2	<div> <div>L</div> <div>22.4</div> <div>24.6</div> <div>24.6</div> </div>
C_5	<div> <div>LT</div> <div></div> <div></div> <div></div> </div>
f_5	<div> <div>ST</div> <div></div> <div></div> <div></div> </div>
f_b	<div> <div>L</div> <div></div> <div></div> <div></div> </div>
b_{10}	<div> <div></div> <div></div> <div></div> <div></div> </div>
E	<div> <div></div> <div></div> <div></div> <div></div> </div>
E_c	<div> <div></div> <div></div> <div></div> <div></div> </div>
G	<div> <div></div> <div></div> <div></div> <div></div> </div>
e	<div> <div></div> <div></div> <div></div> <div></div> </div>
Footnotes	<div> <div></div> <div></div> <div></div> <div></div> </div>

Iss. No.	1		
Date	FEB '62		
App'd by	A.T.		

Data Basis: A

Units: 10^3 lb./in.^2

STATIC PROPERTIES (SHEET 2)

U. K.
D.T.D. 622A, 626A
Magnesium Alloy

Footnotes	Form	Bars and Extrusions
	Specification	D.T.D. 622 A
	Condition	M
	Thickness (in.)	$\begin{matrix} > 0.375 \\ \leq 4.0 \end{matrix}$ $\begin{matrix} \leq 0.375 \\ 0.375 \end{matrix}$
	Cross-Sectional Area (in. ²)	
	f_t	L 448 403
	t_t	L 31.4 269
	C_1	L
	C_2	L
	C_3	T
	f_a	
	f_b	
	b_{10}	
	E	6,450
	E_c	
	G	
	e	10 10
	Footnotes	

GENERAL PROPERTIES

U.K.
2L.121, 2L.122
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Cu	Si	Fe	Ni	Sn			Total of Cu, Si, Fe and Ni.	Mg
Castings	7.5 9.0	0.3 1.0	0.15 0.4	0.15 Max.	0.3 Max.	0.05 Max.	0.01 Max.	0.1 Max.			0.40 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.80				
c	cal./(gm.°C)						
k	cal.cm/(cm. ² sec. °C)	2L.121		0.21 ⁽²⁾	0.23 ⁽³⁾		
		2L.122		0.17 ⁽²⁾	0.21 ⁽³⁾		
α ⁽¹⁾	per °C x 10 ⁻⁶	2L.121		24.9	26.5	27.6	
		2L.122		25.3	26.7	27.9	
ϵ							

(1) Between 20°C and temperature indicated.

(2) Between 70°C and 180°C

(3) Between 180°C and 300°C

Iss. No.	1	2	
Date	FEB 12	JAN 23	
App'd by	AT	A.T.	

(SHEET)

U.K.
2L.i2i, 2L.i22
Magnesium Alloy

Data Basis: A

Units: 10^3 lb./in.^2

Iss. No.	1		
Date	AUG '82		
App'd by	A.T.		

Form	Sand Castings			Chill Castings		
	2L121	2L122	2L122	2L121	2L122	2L122
Specification						
Condition	M	W		M	W	
Thickness (in.)						
Gross-Sectional Area (or weight)						
Type of Test	a	b	c	a	b	c
f_1	20.2			29.1		
f_1	11.2			10.1		
C_1						
C_2						
C_5						
f_a						
f_b						
b_{10}						
E	6,300					
E_c						
G	2,200					
e	2	6	4	10		
Footnotes						

(1) D/t = 11 (2) Data Basis - C. Specimens cut from castings

U.K.
2L.121, 2L.122
Magnesium Alloy

U.K.
2L.121, 2L.122
Magnesium Alloy

Data Basis: C

Units: 10^3 lb/in.^2

Iss. No.	1		
Date	FEB'63		
App'd by	A T		

Footnotes	Test	Specimen	Form and Condition	Stress Ratio	Cycles					
					Nominal	Maximum Stress				
						10^7	3×10^7	6×10^7	9×10^7	10^8
	Rotating Bending	0.3 and 0.4 inch diameter. Sand cast.	2L.121	-1.0	12.1	11.8	11.6	11.5	11.4	11.3
			2L.122	-1.0	12.7	12.1	11.6	11.4	11.2	11.2
	Reversed Flexure	Sand cast	2L.121	-1.0	12.2	11.7	11.4			
			2L.122	-1.0	11.5	11.3				
		Fillet (R=0.04in)	2L.121	-1.0	7.0	6.6				
			2L.122	-1.0	7.6	7.4				
	Footnotes									

U.K.
2L.121, 2L.122
Magnesium Alloy

Iss. No.	1		
Date	FEB '63		
App'd by	A. T.		

Units: Hours, °C, 10³lb./in.²[illegible]

GENERAL PROPERTIES

U.K.
L127, D.T.D. 711A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Zr	Mn	Cu	Si	Fe	Ni						Mg
Castings	3.5 5.5	0.4 1.0	0.15 Max.	0.03 Max.	0.01 Max.	0.01 Max.	0.005 Max.						Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.80				
⁽¹⁾ c	cal./(gm.°C)			0.24			
k	cal.cm/(cm. ² sec. °C)	L 127		⁽²⁾ 0.322	⁽³⁾ 0.324	⁽³⁾ 0.324	
α ⁽¹⁾	per °C x 10 ⁻⁶	L 127		25.6	27.3	28.1	
ϵ							

- (1) Between 20°C and temperature indicated.
 (2) Between 86 and 199°C
 (3) Between 199 and 311°C

Iss. No.	1	2	
Date	FEB '62	JAN '63	
App'd by	AT	AT	

Iss. No.	1	2	
Date	AUG '62	JAN 63	
App'd by	AT	AT	

Units: 10^3 lb./in.^2

Data Basis: A

Form		Sand Castings				Chill Castings				
Specification		D.T.D.711A		L.127		D.T.D.711A		L.127		
Condition		M		P		M		P		
Thickness (in.)										
Gross - Sectional Area (or weight)										
Type of Test		a	b	c ⁽¹⁾	a	b	c ⁽¹⁾	a	b	c ⁽¹⁾
f ₁		29.1			33.6		34.0	33.6		35.8
f ₁		15.7			19.0		21.2	15.7		19.0
C ₁										
C ₂										
C ₅										
f _q							24.2			
f _b										
b ₁₀							39.4			
E										
E _c										
G							59.00			
e	%	7			5			10		7
Footnotes										

(1) Data Basis: C. Specimens cut from castings.

(2) $D/T = 11$

STATIC PROPERTIES (SHEET)

U.K.
L127, D.T.D. 711A
Magnesium Alloy

FATIGUE PROPERTIES

U.K.
L127, D.T.D. 711A
Magnesium Alloy

Data Basis: C

Units: 10^3 lb./in.^2

Iss. No.	1		
Date	FEB '65		
App'd by	A.T.		

Footnotes	Test	Specimen	Form and Condition	Stress Ratio	Cycles			
					10 ¹	3 x 10 ⁴	6 x 10 ⁴	
	Rotating Bending	Sand cast 0.3 inch Diameter	L 127	-1.0	Nominal Maximum Stress			
		Sand cast Plain			9.6	9.4	9.4	
		Sand cast Fillet (R=0.04 in.)			9.2	9.0		
	Reversed Flexure			-1.0	5.6	5.1		
Footnotes								

U.K.
L127, D.T.D. 711A
Magnesium Alloy

Units: Hours, °C, 10³lb./in.²

Iss No	1	
Date	FFB 35	
App'd by	A T	

[illegible]

GENERAL PROPERTIES

U.K.
L.128.D.T.D.748
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Rare Earth Metals	Zr	Mn	Cu	Si	Fe	Ni					Mg
Castings	3.5 5.0	0.75 1.75	0.4 1.0	0.15 Max.	0.03 Max.	0.01 Max.	0.01 Max.	0.005 Max.					Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.83				
$c^{(1)}$	cal./(gm.°C)			0.24			
k	cal.cm./(cm. ² sec. °C)			0.28			
$\alpha^{(1)}$	per °C x 10 ⁻⁶					27	
ϵ							

(1) Between 20°C and temperature indicated.

Iss. No.	1		
Date	FEB '62		
App'd by	AT		

U.K.
L.128, D.T.D. 748
Magnesium Alloy

Units: 10^3 lb./in.^2

Iss. No.	1		
Date	AUG '62		
App'd by	A T		

Footnotes	Form	Sand Casting	Chill Casting
	Specification	L.I28,D.T.D.748	
	Condition	P	
	Thickness (in.)		
	Gross - Sectional Area (or weight)		
	Type of Test	a	b c d b c
	f _t	29.1	30.5 31.4
	f _c	17.9	18.6 17.9
	C ₁		
	C ₂		
	C ₅		
(1)	f _a		20.6
	f _b		
	b ₁₀		36.5
	E	6.500	5.900 6.500
	E _c		
	G		2.500
	e %	3	4
	Footnotes	(2)	

(1) D/t = 11
(2) Data Basis: C. Specimens cut from castings

GENERAL PROPERTIES

U.K.
D.T.D.108,192,196,200A
Nickel Alloy

CHEMICAL COMPOSITION (per cent)

Form	Mn	Fe	Ni								Total Impurities	Cu
All Forms	0.3 2.0	2.5 Max.	64.0 70.0								0.3 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	200	400	600	800
ω	gm./cm. ³	A	8.83				
c	cal./(gm.°C)	A	0.127				
k	cal.cm/(cm ² .sec.°C)	A	0.062	0.065	0.074	0.084	0.094
$\alpha^{(1)}$	per °C x 10 ⁻⁶	A		14.2	15.4		
ϵ							

(1) Between 20°C and temperature indicated.

Iss. No.	Date	App'd by
1	Feb 62	AT

STATIC PROPERTIES
(SHEET 1)

U.K.
D.T.D.10B,192,196,200A
Nickel Alloy

Iss. No.	1	2
Date	FEB '62	JAN '63
App'd by	AT	AT

Data Basis: A

Units: 10^3 lb./in.^2

Form	Sheet	Strip
Specification	D.T.D. 10B	D.T.D.200A
Condition	A	H.D.
Thickness (in.)	>0.02	>0.02
f_t	L 67.2 LT 67.2 ST	101
f_c	L 15.7 LT 15.7 ST	67.2
C_1	L	
C_2	L LT ST	
C_3	L	
f_a		
f_b		
b_{10}		
E		
E_c		
G		
e	% 40	14
Footnotes		

(1) Data Basis: C

Iss. No.	2	
Date	FEB 65	
App'd by	A.T.	

Units: 10³lb./in.² Data Basis: A

STATIC PROPERTIES U.K.
(SHEET 2) DT.D.10B,192,196,200A
Nickel Alloy

Footnotes		Form	Bars, Stampings and Forgings	Bars	
Specification		D.T.D. 192	D.T.D. 196	DT.D. 200A	
Condition		H.R.	C.D.A.	H.D.	
Thickness					
Cross-Sectional Area					
(1)	f_t	L 76.1 T	67.2	101	
	t_t	L T		67.2	
	C_1	L			
	C_2	L 38 T	26.9		
	C_5				
	f_a				
	f_b				
	b_{10}				
	E	26,800			
	E_c				
	G				
	e	% 30	35	14	
Footnotes					

(1) Data Basis: C

SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.K.
D.T.D. 10B, 192, 196, 200A
Nickel Alloy

Iss. No.	1		
Date	AUG '62		
App'd by	AT		

Units: hours, °C, 10³lb./in.²

Data Basis: C

[illegible]

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET)

U.K.
D.T.D. 108, 192, 196, 200A
Nickel Alloy

Units: hours, °C

Data Basis: C

CREEP DATA

Form		Bars														
Condition		H.R.(D.T.D.192)					C.D.A.(D.T.D.196)									
t →		10 ⁵					10 ⁵									
T ↓	Total Deformation Per Cent	Per Cent f_1 , (79×10^3 lb./in. ² at R.T.)					Per Cent f_1 , (84×10^3 lb./in. ² at R.T.)									
399	0.1	26					24									
	1.0	40					35									
427	0.1	20					19									
	1.0	29					29									
482	0.1						9.3									
	1.0	17					19									
538	0.1						4									
	1.0						11									

Iss. No.	1		
Date	AUG '62		
App'd by	AT.		

GENERAL PROPERTIES

U.K.
D.T.D. 703B
Nickel Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	Ti	Cr	Si	Mn	Cu	Fe						Ni (plus Co)
Sheet and Strip	0.08 0.15	0.2 0.6	18.0 21.0	1.0 Max.	1.0 Max.	0.5 Max.	5.0 Max.						Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	200	400	600	800
ω	gm./cm. ³	A	8.36				
$c^{(1)}$	cal./gm.°C	A	0.110				
k	cal.cm/(cm. ² sec. °C)	A		0.038	0.046	0.054	0.062
$\alpha^{(1)}$	per °C x 10 ⁻⁶	A		13.0	13.8	14.7	15.5
ϵ	per cent	Shot blasted and oxidised at 1200 °C			86	92	100

(1) Between 20°C and temperature indicated.

Iss. No.	1	2	
Date	FEB '62	JAN 65	
App'd by	AT	A.T.	

STATIC PROPERTIES (SHEET 1)

U.K.
D.T.D. 703B
Nickel Alloy

Data Basis: C

Units: 10^3 lb./in.^2

Iss. No.	1	2
Date	AUG '62	JAN '63
App'd by	A.T.	A.T.

Form	Sheet
Specification	D.T.D. 703B
Condition	A
Footnotes	
Thickness (in.)	0.04
f_1	L 116
	LT
	ST
t_1	L 58.2
	LT
	ST
C_1	
	L
C_2	LT
	ST
C_5	
f_a	
f_b	
b_{10}	
E	
E_c	
G	
e	% 33
Footnotes	

Iss. No.	1		
Date	Aug '62		
App'd by	A.T.		

Units: 10^3 lb./in.^2

Data Basis: C

STATIC PROPERTIES (SHEET 2)

U.K.
D.T.D. 703B
Nickel Alloy

Footnotes		Form	Bar
Specification			
Condition		A	
Thickness (in.)			
Cross-Sectional Area (in. ²)			
	f_1	L	116.5
		T	
	t_1	L	49.3
		T	
	C_1	L	
		L	
	C_2	T	
		L	
	C_3	L	
	f_4		
	f_6		
	b_{10}		
	E		32,400
	E_c		
	G		
	e	%	44
	Footnotes		

**U.K.
D.T.D. 703B
Nickel Alloy**

**U.K.
D.T.D. 703B
Nickel Alloy**

Units: 10^3 lb./in.^2

Iss. No.	1		
Date	AUG '62		
App'd by	AT		

[illegible]

SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.K.
D.T.D. 703B
Nickel Alloy

Iss. No.	1	2
Date	AUG '62	JAN '63
App'd by	AT	A.T.

Units: hours, °C., 10³ lb./in.²

Data Basis: C

Form	Bar															
Condition	A															
t →																
T ↓	Per Cent f _i (U-6 at 68°F)			Per Cent t _i (49 at 68°F)			Per Cent E (32,400 at 68°F)									
200		91			86										95	
300		94			86										92	
400		92			86										89	
500		87			82										86	
600		71			77										82	
700		44			59										79	
800		25			30										74	
900		14			16											
1000		10			11											

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET)

U.K.
D.T.D. 703B
Nickel Alloy

Units: hours, °C

Data Basis: C

CREEP DATA

Form		Bar															
Condition		A															
t →		10 ²	3 x 10 ²	10 ³	3 x 10 ³	10 ⁴											
T ↓	Total Deformation Per Cent	Per Cent f ₁ (116 x 10 ³ lb./in. ²)															
600	0.1	12.5	10.5	8.8	7.7	6.3											
	0.5	16	14	12.5	10.5	8.7											
	1.0	18	17	14	12.5	10.5											
	3.0		19	17	15	13.5											
650	0.1	8.1	6.4	5.0	4.2												
	0.5	11	9.4	7.9	6.3												
	1.0	12.5	11	9.0	7.3												
	3.0			11	9.2	7.7											
700	0.1	5.4	4.2	3.5	3.1												
	0.5	7.7	6.2	5.0	4.0												
	1.0	8.5	7.1	6.0	4.8												
	3.0			7.3													
750	0.1	3.7	3.1	2.7	2.5												
	0.5	5.2	4.2	3.7	3.3	2.7											
	1.0	6.2	5.2	4.0	3.5												
	3.0			5.4	4.6	3.8											

Iss. No.	1		
Date	FEB 63		
App'd by	A T		

GENERAL PROPERTIES

U.K.
D.T.D. 5003A, 5013A, 5023A
5033A, 5063, 5073
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	Fe	H										Ti
Bars & Billets	0.10 Max.	0.20 Max.	0.013 Max.										Remainder
Sheet, Strip, Tubing	0.10 Max.	0.20 Max.	0.015 Max.										Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		4.51				
c	cal./(gm.°C)		0.123	0.130	0.139	0.143	0.145
k	cal.cm/(cm. ² sec. °C)		0.040	0.038	0.036	0.035	0.036
$\alpha^{(1)}$	per °C x 10 ⁻⁶			9.0	9.1	9.2	9.4
ϵ							

(1) Between 20°C. and temperature indicated.

Iss. No.	Date	App'd by
1	FEB '62	AT

Iss. No.	1	
Date	FLB #2	
App'd by	AT	

Units: 10³ lb./in.²

Data Basis: A

Foot notes		Form		Sheet and Strip						Tubes	
Specification		D.T.D. 5023 A		D.T.D.5033A		D.T.D. 5063		D.T.D. 5073			
Condition		A									
Thickness (in.)		All Thicknesses	> 0-0148	> 0-104	≤ 0-104	> 0-104	All Thicknesses	> 0-0148	> 0-104		
(1)	L	62.7-89.6	62.7-89.6	62.7-89.6	<67.2	<67.2	89.6-116.5	89.6-116.5	89.6-116.5	56	
(2)	f ₁	LT	62.7-89.6	62.7-89.6	<67.2	<67.2	89.6-116.5	89.6-116.5	89.6-116.5		
	ST										
(1)	L		40.3	40.3	29.1	29.1		67.2	67.2	40.3	
(2)	t ₁	LT		40.3	29.1	29.1		67.2	67.2		
	ST										
	C ₁	L									
	L										
	C ₂	LT									
	ST										
	C ₃	L									
	f ₄										
	f _b										
	b ₁₀										
(3)	E										
	E _c										
	G										
	e	%		18		20			12		
Footnotes											

(1) Width of sheet or strip < 9 in (2) Width of sheet or strip > 9 in (3) Data Basis C

STATIC PROPERTIES
(SHEET 1)

U. K.
D.T.D. 5003A, 5013A, 5023A
5033A, 5063, 5073
Titanium Alloy

Iss. No.	1		
Date	Feb '62		
App'd by	A.T.		

Data Basis: A

Units: 10^3 lb./in.^2

STATIC PROPERTIES (SHEET 2)

U.K.
D.T.D. 5003A, 5013A, 5023A
5033A, 5063, 5073
Titanium Alloy

Footnote	Form	Bars and Billets															
	Specification	D.T.D. 5003A	D.T.D. 5013A														
	Condition	A		A													
	Thickness (in.)																
	Cross - Sectional Area (in. ²)																
	f_1	L	62.7 - 89.6		<67.2												
		T															
	t_1	L	40.3		29.1												
		T															
	C_1	L															
		L															
	C_2	T															
		L															
	C_5	L															
	f_a																
	f_b																
	b_{10}																
(1)	E		15,000 - 17,000														
	E_c																
	G																
	e	%	18		20												
	Footnotes																

(1) Data Basis: C

U.K.
D.T.D. 5003A, 5013A, 5023A
5033A, 5063, 5073
Titanium

**D.T.D. 5003A, 5013A, 5023A
5033A, 5063, 5073**

Titanium

Units: 10^3 lb./in.^2

Iss. No.	1		
Date	FEB '63		
App'd by	A.T.		

[illegible]

Static properties of material: $f_t = 85,000 \text{ lb/in}^2$, $f_c = 58,000 \text{ lb/in}^2$, $e = 30\%$

(2) Static properties of material: $f_t = 80,000 \text{ lb./in.}^2$, $f_c = 57,000 \text{ lb./in.}^2$, $e = 30\%$

GENERAL PROPERTIES

U.K.
D.T.D.5053,5143
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Mn	H	Fe									Ti
Bars & Billets	3.0 5.0	3.0 5.0	0.013 Max.	0.20 Max.									Remainder
Forgings	3.0 5.0	3.0 5.0	0.015 Max.	0.20 Max.									Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		4.51				
c	cal./(gm.°C)			0.129	0.134	0.141	0.148
k	cal.cm/(cm. ² sec. °C)		0.017	0.020	0.024	0.025	0.027
$\alpha^{(1)}$	per °C x 10 ⁻⁶			8.4	9.2	9.3	9.7
ϵ							

(1) Between 20°C and temperature indicated.

Iss. No.	1	2	
Date	7/5 '62	11/8 '63	
App'd by	A.T.	A.T.	

STATIC PROPERTIES
(SHEET)

U.K.
D.T.D.5053,5143
Titanium Alloy

Data Basis: A

Units: 10^3 lb./in.^2

Iss. No.	1	2
Date	AUG '62	FEB '63
App'd by	A.T.	A.T.

Form	Bars and Billets	Forgings
Specification	D.T.D. 5053	D.T.D. 5143
Condition	H.T.	H.T.
Thickness (in.)		
Gross - Sectional Area (in. ²)		
f_t	139	139
f_t	128	128
C_1		
C_2		
C_5		
f_a		
f_b		
b_{10}		
E	16,000 - 19,000	
E_c		
G		
e	%	12
Footnotes		

(1) Data Basis: C

**SHORT TIME PROPERTIES
AT ELEVATED TEMPERATURE**
(SHEET)

U.K.
D.T.D.5053,543
Titanium Alloy

Iss. No.	1	
Date	AUG '52	
App'd by	A.T.	

Data Basis: C

Units: hours, °C., 10³lb./in.²

Form	Bar									
Condition	Heat Treated									
t →	0.5		0.5		0.5		0.5		0.5	
T ↓	Per Cent f ₁ (147 at 20°C)		Per Cent f ₁ (137 at 20°C)		Per Cent E 16,800 at 20°C.					
	(1)		(1)							
100	89		85		97					
200	80		75		93					
300	78		70		87					
400	63		51		80					
500					70					
600					59					

(1) These are mean values for material from different manufactures, and with heat treatments varying between the wide limits specified in D.T.D. 5053. Typical properties may vary by as much as ±15% at high temperatures.

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET)

U.K.
D.T.D.5053,5143
Titanium Alloy

Units: Hours, °C

Data Basis: C

CREEP DATA

Form		Bar														
Condition		H.T.														
↑ →			10	100	300	1000	2000									
T ↓	Total Deformation Per Cent	Per Cent f_t ($f_t = 149,000 \text{ lb./in.}^2$ at 22°C)														
22	0.05		80	76	74	73	73									
	0.1		83	80	78	77	76									
	0.2		84	81	80	79	78									
	0.5		85	82	81	80	79									
	1.0		86	84	83											
100	0.05		67	65	64	63	63									
	0.1		69	66	65	64	64									
	0.2		70	67	66	65	65									
	0.5		72	69	68	67	67									
	1.0			72	71	70	70									
200	0.05		56	55	55	55	55									
	0.1		58	57	57	57	57									
	0.2		60	59	59	59	59									
	0.5		63	63	63	62	62									
	1.0															

Iss. No.	1		
Date	FEB 65		
App'd by	AT		

GENERAL PROPERTIES

U.K.
D.T.D. 5083, 5093
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Sn	Fe	H									Ti
Sheet	4.5 5.5	2.0 3.0	0.20 max.	0.015 max.									Remainder
Bars & Billets	4.5 5.5	2.0 3.0	0.20 max.	0.013 max.									Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		4.46				
c	cal./(gm.°C)		(1) 0.113	0.122	0.132	0.139	0.147
k	cal.cm./cm. ² sec. °C		(1) 0.015	0.019	0.028	0.035	0.042
α	per °C x 10 ⁻⁶		(1) 7.8	8.7	10.3	10.9	10.3

(1) At 50°C

Iss. No.	1		
Date	FEB 63		
App'd by	A.T.		

U.K.
D.T.D.5083,5093
Titanium Alloy

Data Basis: A

Units: 10^3 lb./in.^2

Iss. No.	1		
Date	FEB 25		
App'd by	A.T.		

Footnotes		Form	Sheet
		Specification	D.T.D. 5093
		Condition	H.T.
		Thickness	>0.046 >0.104
(1)		L 112 112 112	
(2)		LT 112 112 112	
		ST	
(1)		L 101 101 101	
(2)		LT 101 101 101	
		ST	
		C ₁ L	
		L	
		LT	
		ST	
		C ₅	
		f _a	
		f _b	
		b ₁₀	
(3)		E	15,000-18,000
		E _c	
		G	
		e	% 12
		Footnotes	
		(1) Width < 916 (2) Width > 916 (3) Date	

(1) Width < 9in. (2) Width > 9in. (3) Data Basis: C

Iss. No.	1	
Date	FEB '65	
App'd by	AT	

Data Basis: A

Units: 10^3 lb./in.^2

STATIC PROPERTIES (SHEET 2)

U.K.
D.T.D.5083,5093
Titanium Alloy

#	Footnote	Form	Bars and Billets
		Specification	D.T.D.5083
		Condition	H.T.
		Thickness	
		Gross - Sectional Area	
		f_t	L 112
			T 112
		t_1	L 101
			T 101
		C_1	L
			L
		C_2	T
		C_3	L
		f_a	
		f_b	
		b_{10}	
(1)		E	15,000-18,000
		E_c	
		G	
		ϵ	% 12
		Footnotes	

(1) Data Basis: C

U.K.
D.T.D.5083,5093
Titanium Alloy

Data Basis: C

Units: Hours, °C, 10³lb./in.²

Iss. No.	1		
Date	FEB 63		
App'd by	A.T		

[illegible]

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET 1)

U.K.
D.T.D. 5083,5093
Titanium Alloy

Units: Hours, °C.

Data Basis: C

CREEP DATA

Form		Bar															
Condition		H.T.															
↑ →				10	30	100	300										
T ↓	Total Deformation Per Cent	Per Cent f_1 ($f_1 = 134,000 \text{ lb./in.}^2$ at 20°C)															
20	0.1			68	66	63	62										
	0.5			71	69	67	66										
100	0.1			51	50	49											
	0.5			54	53	52	52										
	1.0			58	57	56	55										
200	0.1			40	40	40	40										
	0.5			45	45	45	45										
	1.0			50	50	50	50										
300	0.1			38	38	38	38										
	0.5			41	41	41	41										
	1.0			44	44	44	44										
400	0.1			36	36	36	36										
	0.5			38	38	38	38										
	1.0			39	39	39	39										
500	0.1			17	13	9											
	0.5			23	19	16											

Iss. No.	Date	App'd by

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET 2)

U.K.
D.T.D. 5083, 5093
Titanium Alloy

Units: Hours, °C.

Data Basis: C

MINIMUM CREEP RATE

Form												
Condition												
Creep Rate												
↓												

TIME TO TENSILE FAILURE

Form	Bar											
Condition	H.T.											
t →		0.1	0.3	1.0	3.0	10	30	100	300	1000	3000	
T ↓	Per Cent f_t ($f_t = 134,000 \text{ lb./in}^2 \text{ at } 20^\circ\text{C}$)											
20		99	99	97	95	92	89	87	85	84	83	
100		84	81	79	78	76	75	74	73	72	72	
200		69	68	67	65	64	64	63	63	63	63	
300		60	58	58	58	58	57	57	57	57	57	
400		56	55	55	55	55	54	54	54	54		
500		53	51	50	48	45	40	33	29	26		

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Date	Feb 63	
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Volume III
Magnesium,
Nickel &
Titanium
Alloys

UNITED STATES SECTION

CONTENTS

1. Introductory Notes
2. Charts as given in the table below

Magnesium Alloy	Title of Chart	Issue No.	Date
AZ31B	General Properties	1	July 1961
	Static Properties, Sheet 1	1	"
	Static Properties, Sheet 2	2	April 1962
	Fatigue Properties	1	July 1961
	Short Time Properties at Elevated Temperature	1	"
	Recovered Properties after Exposure to Elevated Temperature	1	August 1962
	Properties under Load and Elevated Temperature	1	"
AZ61A	General Properties	1	August 1962
	Static Properties	2	"
	Fatigue Properties	1	"
AZ63A	General Properties	1	July 1961
	Static Properties	2	April 1962
	Fatigue Properties	1	July 1961
	Short Time Properties at Elevated Temperature	1	"
AZ80A	General Properties	1	July 1961
	Static Properties	1	"
	Fatigue Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
	Recovered Properties after Exposure to Elevated Temperature	1	August 1962
	Properties under Load and Elevated Temperature Sheet 1	1	"
	Properties under Load and Elevated Temperature Sheet 2	1	"
AZ91C	General Properties	1	July 1961
	Static Properties	2	April 1962
	Fatigue Properties	1	July 1961
	Short Time Properties at Elevated Temperature	1	"

Cont....

CONTENTS Continued

Magnesium Alloy	Title of Chart	Issue No.	Date
AZ92A	General Properties	1	July 1961
	Static Properties	2	April 1962
	Fatigue Properties	1	July 1961
	Short Time Properties at Elevated Temperature	1	"
	Recovered Properties after Exposure to Elevated Temperature	1	August 1962
HK31A	General Properties	1	July 1961
	Static Properties, Sheet 1	2	April 1962
	Static Properties, Sheet 2	2	"
	Fatigue Properties	1	July 1961
	Short Time Properties at Elevated Temperature	1	August 1962
	Recovered Properties after Exposure at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature	1	"
M1A	General Properties	1	July 1961
	Static Properties, Sheet 1	1	August 1962
	Static Properties, Sheet 2	2	"
	Fatigue Properties	1	"
ZK60A	General Properties	1	July 1961
	Static Properties	1	"
	Fatigue Properties	1	"
AM100A	General Properties	1	July 1961
	Static Properties	2	April 1962
Nickel Alloy			
Inconel X	General Properties	1	July 1961
	Static Properties, Sheet 1	1	August 1962
	Static Properties, Sheet 2	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature, Sheet 1	1	"
	Properties under Load and Elevated Temperature, Sheet 2	1	"
Titanium Alloy			
Commercially pure titanium	General Properties	1	July 1961
	Static Properties, Sheet 1	1	August 1962
	Static Properties, Sheet 2	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature	1	"

Cont....

CONTENTS *Continued*

<i>Titanium Alloy</i>	<i>Title of Chart</i>	<i>Issue No.</i>	<i>Date</i>
8Mn	General Properties	1	July 1961
	Static Properties	1	August 1962
	Fatigue Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
4Al-4Mn	General Properties	1	July 1961
	Static Properties	2	August 1962
	Fatigue Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature	1	"
6Al-4V	General Properties	1	July 1961
	Static Properties, Sheet 1	1	"
	Static Properties, Sheet 2	1	"
	Short Time Properties at Elevated Temperature	1	August 1962
	Recovered Properties after Exposure at Elevated Temperature	1	"

August 1962

UNITED STATES SECTION

INTRODUCTORY NOTES

The *Introduction to Volume III* of this handbook explains the general layout adopted for the presentation of the data, together with details of the properties considered and the explanation of various terms. The purpose of the following notes is to amplify these points, where necessary, in relation to those United States materials which are included.

MAGNESIUM ALLOY DESIGNATIONS

The designations of the United States magnesium alloys are descriptive of the composition of the material. The designation consists of an initial group of letters indicating the main alloying elements, followed by numbers which signify the approximate average percentage content of each of these elements. A final letter is added to indicate any modification of the basic composition.

The elements indicated by the initial letters are as follows:

A - Aluminium	M - Manganese
H - Thorium	Z - Zinc
K - Zirconium	

Thus AZ91C is the third modification of a magnesium alloy containing 9 per cent aluminium and 1 per cent zinc, and AM100A is a magnesium alloy containing 10 per cent aluminium and less than 0.5 per cent manganese.

NICKEL ALLOY DESIGNATIONS

The commercial designations are used for the United States nickel alloys.

TITANIUM DESIGNATIONS

The designations used for the United States titanium alloys are simple descriptions of the approximate average percentages of the main alloying elements. E.g. 6Al-4V is a titanium alloy containing 6 per cent aluminium and 4 per cent vanadium.

The various grades of commercially pure titanium are designated in accordance with the percentage purity of the titanium e.g. 99Ti or 99+Ti, or alternatively in accordance with F_{ty} of the material in 10^3 lb./in.^2 e.g. Ti-70 has a yield strength of $70 \times 10^3 \text{ lb./in.}^2$

SPECIFICATIONS

As for all the National Sections, the specifications appropriate to the various forms and conditions of the alloys are indicated on the *Static Properties* charts wherever possible. The sources of these specifications are indicated below:-

MIL-M MIL-N MIL-T	{ These are Military Specifications approved by the Department of Defense for use by the Department of the Army, the Navy and the Airforce. Copies may be obtained from Commander, Wright-Patterson AFB, Ohio, Attn. EWBFE.
QQ-M WW-T	{ These are Federal Government Specifications and copies may be obtained from the General Services Administration, Washington D.C.
AMS	{ These specifications are non-Government Specifications issued by S.A.E. and may be obtained from the Society of Automotive Engineers, 485 Lexington Avenue, New York 17, New York.

MATERIALS COVERED

This Section of the Handbook lists the available established data on several magnesium, nickel and titanium alloys produced in the United States. These alloys are those most widely used structurally in aircraft, neglecting as explained in the *Introduction to Volume III*, those alloys used solely for castings or for rivets, with the exception of magnesium castings.

Different forms of a particular alloy are usually covered by a different specification for each form. For this reason the alloys are listed below together with the more usual forms in which they are produced, and the specifications relevant to those forms.

MAGNESIUM ALLOYS

Designation	Specifications	Form
AZ31B	QQ-M-44; AMS4375; AMS4376; AMS4377	Sheet and plate ¹
	QQ-M-31	Extruded bars; rods; solid shapes & hollow shapes
	WW-T-825	Tubing
AZ61A	QQ-M-31; AMS4350	Extruded bars; rods; solid shapes & hollow shapes
	WW-T-825	Tubing
	QQ-M-40; AMS4358	Forgings

Cont....

<i>Designation</i>	<i>Specifications</i>	<i>Form</i>
AZ83A	QQ-M-56; AMS4426, AMS4422; AMS4424	Sand castings
	QQ-M-55; AMS4420; AMS4422; AMS4424	Permanent mold castings
AZ80A	QQ-M-31	Extruded bars; rods and solid shapes
	QQ-M-40	Forgings
	AMS4360	Die-forgings and hand forgings
AZ91C	QQ-M-56; AMS4437	Sand castings
	QQ-M-55; AMS4437	Permanent mold castings
AZ92A	QQ-M-56; AMS4434	Sand castings
	QQ-M-55; AMS4434	Permanent mold castings
HK31A	M11-M-26075; AMS4384; AMS4385	Sheet and plate
	QQ-M-56; AMS4445	Sand castings
M1A	AMS4370	Sheet
	QQ-M-31	Extruded bars; rods; solid & hollow shapes
	WW-T-825	Tubing
	QQ-M-40	Forgings
ZK60A	QQ-M-31; AMS4352	Extruded bars; rods; solid & hollow shapes
	WW-T-825; AMS4352	Tubes
	QQ-M-40; AMS4362	Die forgings
	AMS4362	Hand forgings
AM100A	QQ-M-55; AMS4483	Permanent mold castings

Cont....

NICKEL ALLOY

<i>Designation</i>	<i>Specifications</i>	<i>Form</i>
Inconel X	MIL-N-7786; AMS5542 AMS5667	Sheet and strip Bars; forgings

TITANIUM ALLOYS

Commercially Pure	MIL-T-7993; AMS4900; AMS4901; AMS4902 MIL-T-9047 Class I; AMS4921 AMS4941	Sheet; strip & plate Bars; forgings & forging stock Welded tubing
8Mn	MIL-T-009046 Class I; AMS4908	Sheet and strip
4Al-4Mn	MIL-T-9047 Class 6; AMS4925	Bars; forgings & forging stock
6Al-4V	MIL-T-009046 Class 2; AMS4911 MIL-T-9047 Class 5; AMS4928	Sheet & strip Bars; forgings & forging stock

CHEMICAL COMPOSITION

The *General Properties* charts give the chemical composition by quoting the limits of the alloying elements as a percentage by weight of the total.

CONDITION

The 'Condition' row on the charts refers to the type of heat treatment and conditioning. The conditions of the various alloys are indicated on the charts by symbols which are defined briefly as follows:-

MAGNESIUM

- F - As fabricated.
- O - Annealed, recrystallized (wrought products only).
- H - Strain hardened.

- H1 plus one or more digits - Strain hardened only.
- H2 plus one or more digits - Strain hardened and then partially annealed.
- H3 plus one or more digits - Strain hardened and then stabilized.
- W - Solution heat treated, unstable temper.
- T - Treated to produce stable tempers other than F, O or H.
- T2 - Annealed (cast products only).
- T3 - Solution heat treated and then cold worked.
- T4 - Solution heat treated.
- T5 - Artificially aged only.
- T6 - Solution heat treated and then artificially aged.
- T7 - Solution heat treated and then stabilized.
- T8 - Solution heat treated, cold worked and then artificially aged.
- T9 - Solution heat treated, artificially aged and then cold worked.
- T10 - Artificially aged and then cold worked.

NICKEL

Details of the heat treatments for Inconel X are given in the following table:

Condition Treatment	Fully heat treated (Full HT)	Precipitation heat treated
Heated at:- for:-	2100 to 2125°F 2 to 4 hours	1900 to 2000°F 15 to 30 min.
Cooling:-	in air	oil or water quench
Heated at:- for:-	1525 to 1575°F 24 hours	1275 to 1325°F 20 to 30 hours
Cooling:-	rapidly in air to 1300°F maximum	
Heated at:- for:-	1275 to 1325°F 20 hours	
Cooling:-	in air	

TITANIUM

Annealing and heat treating temperatures and times for titanium and titanium alloys are given in the following table.

Material	Commercially Pure	3Mn	4Al-4Mn		6Al-4V	
Condition Treatment	Annealed (Ann.)	Annealed (Ann.)	Annealed (Ann.)	Aged	Annealed Sheet	Annealed Bar & Forgings
Heated at:- for:-	1000-1300°F 1 to 2 hours	1300°F 1 hour	1300°F 2 hours	1440 to 1460°F 1 to 2 hours	1300- 1350°F 1 hour	1275- 1325°F 2 hours
Cooling:-	in air	at 300°F per hour max. to 1050°F	at 300°F per hour max.	water quench	at 50°F per hour max. to 800°F	in air
Heated at:- for:-				900°F 8 hours		

NOTATION

The notation used in this Section of the Handbook for the various physical and mechanical properties of the U.S. alloys is defined in the *Notation* chart in the *Introduction to Volume III*. This chart also compares the notations used for the other National Sections. Points where any amplification is needed are dealt with under the appropriate headings below.

UNITS

The units used for the various parameters and properties are indicated on each of the charts. For mechanical properties the stresses and moduli are given in units of 10^3 lb./in.^2 , whilst temperature is quoted in degrees Fahrenheit. For conversion to other units see the *Conversion Scales* chart given in the *Introduction to Volume III*.

DATA BASIS

The *Introduction to Volume III* of this Handbook describes the use of the symbols 'A', 'B' and 'C' denoting the data basis of the values for the various properties given on the charts. Special aspects of this in relation to the values quoted for the U.S. alloys are outlined below.

- A - This indicates that the values listed are the minimum to be expected for the given material. The only values considered 'guaranteed minimum' are those for F_{tu} and F_{ty} which are marked as data basis 'A' and which have been published by the material producer for the grain direction accepted for commercial guarantees. The remaining values marked as data basis 'A' are 'derived' values; that is, sufficient tests have been made to ascertain that if the material meets the 'A' value for F_{tu} , that material will have compressive, shear and bearing strengths equal to or exceeding the values listed.
- B - Insufficient data are available on the U.S. magnesium, nickel and titanium alloys to quote any values to Data Basis 'B'.
- C - This indicates that the values listed are typical for the material, there being insufficient data to determine values for Basis 'A' or 'B'.

In general the data basis used on any chart is shown at the top of the chart, but special attention must be paid to footnotes which sometimes indicate a different data basis for some particular part of the chart.

STATIC PROPERTIES CHARTS: WROUGHT ALLOYS

TENSILE AND COMPRESSIVE STRENGTHS

The symbol F_{ty} denotes the 0.2 per cent off-set yield stress in tension. In the United States this is generally termed the 'yield stress in tension'. Similarly, F_{cy} is the 0.2 per cent yield stress in compression or the 'yield stress in compression'.

The sub-headings 'L', 'LT' and 'ST' used with the tensile and compressive strengths on the *Static Properties* charts refer to the longitudinal, long transverse and short transverse directions respectively.

The form and dimensions of the specimens used to determine the tensile and compressive strengths are in accordance with the requirements of Federal Test Specification QQ-M-151a which may be obtained from the General Services Administration, Washington D.C. The yield strength is determined by the off-set or extension-under-load methods.

STRAIN RATES

Data on the Static Properties charts are based on strain rates of 0.003 to 0.007 inches per inch per minute where possible. Where data are used which were obtained at other strain rates it has been ascertained that the rate is sufficiently close to the 0.003 to 0.007 range for strain rate effects to be insignificant.

ELASTIC AND SHEAR MODULI

The sub-headings 'L' and 'T' used with the elastic moduli on the *Static Properties* charts refer to the longitudinal and transverse directions respectively. Although the values quoted for moduli are not strictly minimum values they may be regarded as Data Basis 'A' values unless otherwise indicated because they are very carefully chosen.

ELONGATION

The values of elongation given on the charts are quoted as the percentage elongation, at fracture, over a gauge length of 2 inches. The tests are made on the standard tension test specimen appropriate to the form and thickness of the material being tested as indicated in the Federal Specification QQ-M-151a. In general the elongation values are measured in the longitudinal direction. The values for the transverse direction may be appreciably less. Where values in both directions are known this is given on the charts.

The elongation values quoted on the *Static Properties* charts are all to Data Basis 'A'.

STATIC PROPERTIES CHARTS: CAST MAGNESIUM ALLOYS

Static properties are given for separately cast test specimens (Type of Test 'a'). The mechanical properties of production castings may be as low as 75 per cent of the tabulated values. Non-destructive and proof testing requirements for the acceptance of castings used in primary, secondary or non-structural applications are given in the specification Mil-C-6021D obtainable from:

Commander,
Wright Patterson A.F.B.,
Ohio,
Attn: EWBFE.

The allowable stresses used in design are left to the discretion of the designer.

Minimum and average tensile properties for specimens cut from castings are given in the appropriate material specifications.

The form and dimensions of the specimens used to determine the tensile strengths are in accordance with the requirements of Federal Test Specification QQ-M-151a.

FATIGUE PROPERTIES

The data given on the *Fatigue Properties* Charts cover tests in rotating bending, reversed flexure and repeated axial loading. A brief description of the various specimens tested together with the theoretical stress concentration factor in the case of notched specimens is given on the charts.

For rotating bending, the tests were carried out on R.K. Moore rotating-beam fatigue machines, using 0.30 inch diameter machined and polished specimens. Die-cast specimens were cast to shape.

For reversed flexure, the tests were carried out in Krouse constant-deflection type fatigue testing machines on 0.25 inch thick cast and forged specimens and 0.064 inch thick sheet specimens. Sand-cast specimens were machined; all other specimens received no special surface treatment.

The repeated axial load tests were made in Krouse direct tension-compression fatigue machines on 0.084 inch by 1 inch sheet specimens and 0.3 inch diameter machined and polished sand cast and extruded sections.

In all cases the 'Nominal Maximum Stress' quoted on the charts is the maximum stress across the critical section of the specimen determined at the maximum load of the fatigue cycle, without correction for stress concentration effects. The Stress Ratio quoted on the charts is the ratio minimum to maximum stress during the fatigue cycle with compressive stress being taken negative and tensile stress positive. It should be noted that there is always a wide scatter of results with tests of this type, and the values given on the charts represent mean lines through the scatter bands except for magnesium alloys where the upper and lower limits of scatter are given.

ELEVATED TEMPERATURE DATA

On these charts the data are presented as percentages of the appropriate room temperature values, which are indicated when known in brackets at the head of the column. The data have been obtained from uncoated specimens heated in air.

Except for details of the gripped portion, specimens used for the elevated temperature tests are similar in dimensions to those used for the corresponding room temperature tests.

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE: CREEP DATA

On these charts the data are presented in the form of the stress required, as a percentage of room temperature F_{tu} , to produce a given total deformation at a given temperature in a given time.

Total deformation is defined as the total strain at any given time, including initial strain but not including thermal expansion. This may be used to estimate the deformation or deflection of structural parts.

July 1962

Iss. No.	1		July '62
Date			

GENERAL PROPERTIES

U.S.
AZ 31B
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Ca	Cu	Ni	Fe			Others	Mg
All Forms	2.5 3.5	0.7 1.3	0.20 Min	0.10 Max	0.04 Max	0.05 Max	0.005 Max	0.005 Max			0.30 Max	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³	0	1.78	1.77	1.75	1.74	
c	cal./(gm.°C)	0	0.233	0.25	0.27	0.285	
K	cal.cm./(cm ² sec. °C)	(2) 0	0.19	0.21	0.24	0.26	
		(4) 0	0.20	0.22	0.25	0.26	
α ⁽¹⁾	per °C x 10 ⁻⁶	(2) 0	25.8	26.4	26.6	27.1	
		(3) 0	23.7	24.2	25.3	25.8	
		(4) 0	26.4	26.4	26.7	27.4	
ϵ ⁽⁵⁾			0.12	0.13	0.15	0.16	

- (1) Value between 20°C and temperature indicated. (2) Longitudinal direction.
(3) Long transverse direction. (4) Short transverse direction.
(5) Polished surface.

Iss. No.	Date	App'd by
1	JULY '51	AT

Iss. No	1	2
Date	JULY '61	APRIL '62
App'd by	AT	AT

Units: 10^3 lb./in.^2

Data Basis: A

STATIC PROPERTIES (SHEET 2)

U.S.
AZ 31B
Magnesium Alloy

Form	Extruded bars, Rod and Solid Shapes	Extruded Hollow Shapes	Extruded Tubes
Specification	QQ-M-31		WW-T-825
Condition	F		
Thickness (in.)	0.249 0.250 1.500 1.499 2.499		0.028 0.251 0.250 0.750
Cross-Sectional Area (in. ²)			
F_{tu}	L 35 T 35 34 32 32 32		
F_{ty}	L 21 T 22 22 16 16 16		
F_{ci}			
F_{oy}	L 12 T 12 10 10 10		
F_{cs}			
F_{su}	18 18 18 36 36 45 45 23 23 23		
F_{bru} (e/D=1.5)	36 36 45 45 23 23		
F_{bry} (e/D=2.0)	45 45 23 23		
E	6,500		
E_c	6,500		
G	2,400		
e	7 7 7 7 8 8 4		
Footnotes			

SHORT TIME PROPERTIES
AT ELEVATED TEMPERATURE
(SHEET)

U.S.
AZ 31B
Magnesium Alloy

Data Basis: C

Units: hrs., °F., 10³lb./in.²

Form	All Forms										Sheet					
Condition	H 24										O					
t →	Per Cent F _{tu}	Per Cent F _{ty}	Per Cent F _{cy}	Per Cent F _{su}	Per Cent F _{br}	Per Cent E	Per Cent F _{tu} (38 at 78°F)	Per Cent F _{ty} (23 at 78°F)	Per Cent F _{cy} (17 at 78°F)	Per Cent F _{su} (17 at 78°F)	Per Cent F _{br} (31 at 78°F)	Per Cent E (6,600 at 78°F)				
T ↓																
100	98	96	98	98	99	98	97	96	100	99	97				98	
200	82	75	87	90	92	95	84	83	95	97	89				95	
300	54	44	72	76	73	81	58	59	82	91	71				91	
400	30	23	44	47	32	68	36	39	61	63	52				76	
500	19	13	23	31	22	53	22	22	39	38	33				64	
600	13	7	14	20	16	39	16	9	24	25	23				50	

(1) e/D = 1.5

Iss. No.	1		
Date	JULY '61		
App'd by	AT		

Iss. No.	1	
Date	AUG '62	
App'd by	A T	

RECOVERED PROPERTIES AFTER EXPOSURE TO ELEVATED TEMPERATURE

U.S.
AZ 31 B
Magnesium Alloy

Data Basis: C

Units: hrs., °F., 10³ lb./in.²

Form	Sheet											
Condition	H 24											
t →	91	0001	91	0001	91	0001	91	0001	91	0001	91	0001
T ↓	Per Cent F _{tu} (41 at 78°F)	Per Cent F _{ty} (32 at 78°F)	Per Cent F _{ty} (32 at 78°F)	Per Cent F _{cy} (24 at 78°F)	Per Cent F _{tu} (41 at 78°F)	Per Cent F _{ty} (32 at 78°F)	Per Cent F _{ty} (32 at 78°F)	Per Cent F _{cy} (24 at 78°F)	Per Cent F _{tu} (41 at 78°F)	Per Cent F _{ty} (32 at 78°F)	Per Cent F _{ty} (32 at 78°F)	Per Cent F _{cy} (24 at 78°F)
100	100	100	100	100	100	100	100	100	100	100	100	100
200	100	100	100	101	101	100	100	100	100	100	100	100
300	98	98	98	98	95	97	88					
400	91	91	84	81	79	75						
500	90	90	76	76	73	72						
600	88	88	73	73	71	71						

Iss. No.	1	
Date	AUG '62	
App'd		

PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE
(SHEET 1)

U.S.
AZ 31B
Magnesium Alloy

Units: hrs., °F.

Data Basis: C

CREEP DATA

Form		Sheet													
Condition		H 24													
t →		0.1	0.2	0.5	1.0	2.0	5.0	10	20	50	100	200	500	1000	
T ↓	Total Deformation Per Cent	Per Cent F_{tu}													
300	2				45	38	31	27	25	24					
	3					43	34	30	27	25					
	4					46	36	32							
	5					47	38	33	30						
400	2		29	25	23	20	16								
	3		29	26	24	22	19	15							
	4		29	27	25	23	20	17	13						
	5		29	27	25	23	21	19	16						
500	2		18	16	14	12	8								
	3			17	15	14	10	7							
	4			18	16	15	12	9	6						
	5				17	15	13	10	7						
600	2			7	6	5	3	2							
	3			9	8	7	5	3	1						
	4				9	7	6	4	2						
	5				10	8	6	5	3	1					

Iss. No.	1		
Date	Aug '62		
App'd by	A.T.		

GENERAL PROPERTIES

U.S.
AZ 61A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu	Ni	Fe				Others	Mg
Extrusions,	5.8	0.40	0.15	0.30	0.05	0.005	0.005				0.30	Remainder
Forgings	7.2	1.5	Min.	Max.	Max.	Max.	Max.				Max.	

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.79				
$c^{(1)}$	cal./(gm.°C)		0.25				
K	cal.cm/(cm. ² sec. °C)			0.19	0.19	0.19	
$\alpha^{(2)}$	per °C x 10 ⁻⁶			25			
ϵ							

(1) At 25°C

(2) Between 18°C and temperature indicated

Iss. No	1		
Date	Aug '62		
App'd by	AT		

STATIC PROPERTIES

(SHEET)

U.S.
AZ61A
Magnesium Alloy

Data Basis: A

Units: 10^3 lb./in.^2

Iss. No	1	2
Date	JULY '61	AUG '62
App'd by	AT	AT

Form	Extruded bar, rod and solid shapes	Extruded hollow shapes	Extruded tubes	Forgings
Specification	QQ-M-31, AMS 4350	WW-T-825	QQ-M-40 AMS 4358	
Condition	F			
Thickness (ins.)	≤ 0.250 0.249	0.250-0.500 2.499-4.799	0.028 0.750	< 6 (4)
Cross-Sectional Area (in ²)	≤ 25			
F_{tu}	L 38 T 21	3 36 24 16	36	38
F_{ty}	L 21 T 24	24 16	16	22
F_{cl}	L 14 T 14	11	11	14
F_{cy}	L 14 T 14	11	11	14
F_{cs}	L 14 T 14	11	11	14
F_{su}	L 19 T 19	19	19	19
F_{bru}	$\phi D = 1.5$ 45	45	45	50
F_{bry}	$\phi D = 2.0$ 55	55	55	60
F_{bry}	$\phi D = 1.5$ 28	28	28	28
F_{bry}	$\phi D = 2.0$ 32	32	32	32
E	6,300			
E_c	6,300			
G	2,400			
e	8	9	7	5
Footnotes	(1)	(2)	(3)	(4)

(1) AMS 4350 gives $F_{ty} = 20$
(2) AMS 4350 gives $F_{tu} = 40$
(3) AMS 4350 only.
(4) For hand forgings

Iss. No.	1		
Date	AUG '62		
App'd by	A.T.		

Units: 10^3 lb./in.^2

Data Basis: C

Footnotes	Test†	Specimen	Condition	Stress Ratio	Cycles					
					Nominal			Maximum Stress		
					10^5	10^6	10^7	10^8		
	Rotating Bending	0.3 in. diameter machined from extrusions.	F	-1.0	24 30	22 27	20 25	18 23		
		0.3 in. diameter machined from forgings.			24 28	21 25	19 23	17 22		
	Reversed Flexure	0.25 in. thick from extrusions	F	-1.0	17 19	12 15	11 14			
		0.25 in. thick from forgings Surface as forged.			15 18	11 13	10 12			
	Repeated Axial Load	0.3 in diameter machined from extrusions.	F	0.25	23 26	19 22	18 20			
	Footnotes									

FATIGUE PROPERTIES

U.S.
AZ61A
Magnesium Alloy

GENERAL PROPERTIES

U.S.
AZ63A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu	Ni					Others	Mg
Sand Castings	5.3 6.7	2.5 3.5	0.15 Min.	0.30 Max.	0.10 Max.	0.01 Max.					0.30 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.82				
c	cal./(gm.°C)		0.25				
K	cal.cm/(cm. ² sec. °C)	F	0.141				
		T4	0.156				
		T5	0.125				
		T6	0.145				
$\alpha^{(1)}$	per °C x 10 ⁻⁶			25			
ϵ							

(1) Between 18°C and temperature indicated.

Iss. No.	1		
Date	July '51		
App'd by	A T		

Iss. No.	1	2
Date	JULY '61	APRIL '62
App'd by	AT	AT

Units: 10^3 lb./in.^2

Data Basis: A

Footnote	Form	Sand and Permanent Mould Castings											
		Specification		QQ-M-55, QQ-M-56									
				AMS 4420		AMS 4422		AMS 4424					
Condition		F	T4	T5	T6								
Thickness (in.)													
Gross - Sectional Area													
(1)	Type of Test	a	a	a	a	a	a	a	a	a	a	a	a
	F _{tu}	24	34	34	24	34	16	16	19	50	65	36	45
	F _{ty}	10	10	10	11	11	16	16	36	45			
	F _{cl}												
	F _{cy}	10	10	10	11	11	16	16	36	45			
	F _{c5}												
	F _{su}	16	17	17									
	F _{bru}	36	36	36	50	50	65	65	36	45			
	F _{bry}	28	32	32	36	36							
	E	6,500											
	E _c	6,500											
	G	2,400											
	e	4	7	7	2	2	3	3					
	Footnotes												

(1) Mechanical Properties are based on the minimum guaranteed tensile properties from separately cast test bars. The Mechanical Properties of production castings may be as low as 75% of the tabulated values.

STATIC PROPERTIES

(SHEET)

U.S.
AZ 63A

Magnesium Alloy

FATIGUE PROPERTIES

U.S.
AZ63A
Magnesium Alloy

Units: 10^3 lb/in^2

Data Basis: C

Iss. No.	1		
Date	JULY '61		
App'd by	AT		

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles				
					10 ⁵	10 ⁶	10 ⁷	10 ⁸	
					Nominal Maximum Stress				
	Rotating Bending	0.3 in. diameter sand cast specimens.	F	-1.0	15 18	12 15	10 13	9.5 12	
			T4	-1.0	18 23	16 21	14 19	13 17	
			T6	-1.0	17 20	15 18	12 16	11 15	
	Reversed Flexure	0.25 in. thick cast specimens	T4	-1.0	13 16	11 14	10 12		
	Repeated Axial Load	0.3 in diameter machined and polished from castings.	F	0.25	22 25	20 23	18 21		
			T4	0.25	23 27	21 24	18 21		
			T6	0.25	25 30	23 26	22 25		
	Footnotes								

U.S.
AZ63A
Magnesium Alloy

Units: hours, °F.

Iss. No.	1		
Date	July '61		
App'd by	AT		

GENERAL PROPERTIES

U. S.
AZ 80 A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu	Ni	Fe				Others	Mg
All. Forms	7.8 9.2	0.20 0.8	0.12 min.	0.30 max.	0.05 max.	0.005 max.	0.005 max.				0.30 max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.80				
c	cal./(gm.°C)		0.25				
K	cal.cm./(cm. ² sec. °C)			0.182	0.182	0.182	
α (1)	per °C x 10 ⁻⁶			25.2			
ϵ							

(1) Between 18° and temperature indicated.

Iss. No.	Date	App'd by
1	JULY '61	AT

Iss. No	1	
Date	JULY 51	
App'd by	AT	

Units: 10^3 lb./in.^2

Data Basis: A

Form	Extruded bars, rods and solid shapes.						Forgings	Die Forgings	Hand Forgings
Specification	QQ-M-31						QQ-M-40	AMS 4360	
Condition	F						F	T5	T5
Thickness (in)	≤ 0.249 0.250 1.500 0.499 1.499 2.499							<2 OR <50	>2 >50
Weight of Forging lbs.									
F_{tu}	L	43	43	43	47	48	48	42	42
	T							34	
F_{ty}	L	28	28	28	30	33	33	28	28
	T							22	
F_{cl}									
F_{cy}			17	17		28	27	18	25
F_{cs}									
F_{su}		19	19	19	20	20	20	20	20
F_{bru}	$\frac{\%D}{1.5}$	48	48	48				50	
	$\frac{\%D}{2.0}$	56	56	56				70	
F_{bry}	$\frac{\%D}{1.5}$	36	36	36				42	
	$\frac{\%D}{2.0}$	40	40	40					
E							6,500		
E_c							6,500		
G							2,400		
e	%	9	8	6	4	4	4	5	2
Footnotes								(1)	(2)

(1) Minimum values of not less than 8 specimens cut from thick and thin sections, equal numbers of specimens to be tested in the longitudinal and transverse directions.

(2) Average values of not less than 8 specimens, as in footnote (1)

STATIC PROPERTIES (SHEET)

U. S.
AZ 80 A
Magnesium Alloy

FATIGUE PROPERTIES

U. S.
AZ 80 A
Magnesium Alloy

Data Basis: C

Units: 10³ lb./in.²

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles									
					Nominal					Maximum Stress				
					10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷
	Rotating Bending	0.3 in. diameter specimen machined and polished from extrusion.	F	-1.0	25 30	23 28	21 26	20 24						
			F	-1.0	28 30	24 26	20 22	18 20						
		0.3 in. diameter specimens, machined and polished from forging.	T 4	-1.0		21 24	18 21	16 18						
			T 5	-1.0	26 30	22 25	19 21	16 19						
			T 6	-1.0	23 27	19 22	16 19	14 16						
			F	-1.0	19 21	13 16	12 14							
		0.25 in. thick as forged.	T 6	-1.0	16 20	13 16	12 15							
	Footnotes													

Iss. No.	1		
Date	JULY '61		
App'd by	AG		

U. S.
AZ 80 A
Magnesium Alloy

Units: hours, °F.

Iss. No.	2		
Date	JULY '61		
App'd by	AT.		

[illegible]

**U. S.
AZ 80 A
Magnesium Alloy**

Units: hours, °F., 10³lb./in.²

Iss. No.	1		
Date	AUG '62		
App'd by	A.T.		

[illegible]

U. S.
AZ 80
Magnesium Alloy

Data Basis: C

[illegible]

Iss. No.	1		
Date	AUG '82		
App'd by	A.T		

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET 2)

**U. S.
AZ 80 A
Magnesium Alloy**

Units: hours, °F.

Data Basis: C

MINIMUM CREEP RATE

Form	Forgings													
Condition	T 5													
Creep Rate			5×10^{-7}	10^{-6}	2×10^{-6}	5×10^{-6}	10^{-5}	2×10^{-5}						
T ↓	per cent F_{tu}													
200			24	28	33	38	42	46						
300				3	5	10	16							

TIME TO TENSILE FAILURE

Form	Forgings													
Condition	T 5													
t →		100	200	500	1000	2000								
T ↓	per cent F_{tu}													
200				50	48	46								
300		24	23	22	21	20								

Iss No	1	
Date	AUG '62	
App'd by	AT	

GENERAL PROPERTIES

U.S.
AZ 91C
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu	Ni					Others	Mg
Sand	8.1	0.4	0.13	0.30	0.10	0.01					0.30	Remainder
Castings	9.3	1.0	Min.	Max.	Max.	Max.					Max.	

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.81				
C	cal./(gm.°C)		0.25				
K	cal.cm./(cm. ² sec. °C)	F	0.129				
		T4	0.109				
		T6	0.134				
$\alpha^{(1)}$	per °C x 10 ⁻⁶			25			
ϵ							

(1) Value between 20 and 100°C.

Iss. No.	Date	App'd by
1	July '51	A.T.

STATIC PROPERTIES
(SHEET)

U.S.
AZ 91C
Magnesium Alloy

Data Basis: A

Units: 10³lb/in.²

Iss. No	1	2	
Date	JULY '61	APRIL '62	
App'd by	A.T.	A.T.	

Footnotes	Form	Sand and Permanent Mould Castings.			
	Specification	QQ-M-55 QQ-M-56			
	Condition	F	T4	T5	T6
	Thickness (in.)				
(1)	Type of Test	a	a	a	a
	F _{tu}	18	34	20	34
	F _{ty}	10	10	11	16
	F _{cl}				
	F _{cy}	10	10	11	16
	F _{cs}				
	F _{su}		17		19
	F _{bru} % _p =1.5		36		50
	F _{bry} % _p =2.0		50		65
	F _{bry} % _p =1.5		32		36
	F _{bry} % _p =2.0		36		45
	E	6,500			
	E _c	6,500			
	G	2,400			
	e		7	2	3
	Footnotes				

(1) Mechanical Properties are based on the minimum guaranteed tensile properties from separately cast test bars. The Mechanical Properties of production castings may be as low as 75% of the tabulated values.

**U.S.
AZ 91C
Magnesium Alloy**

Units: 10^3 lb/in.^2

Iss. No.	1		
Date	JULY '61		
App'd by	AT		

[illegible]

**U.S.
AZ91C
Magnesium Alloy**

Units: hours, °F., 10³lb./in.²[illegible]

GENERAL PROPERTIES

U.S.
AZ 92A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu	Ni					Others	Mg
Castings	8.3 9.7	1.6 2.4	0.10 Min.	0.30 Max.	0.10 Max.	0.01 Max.					0.30 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.82				
$c^{(1)}$	cal./(gm.°C)		0.25				
K	cal.cm./(cm. ² sec. °C)			0.161	0.161	0.161	
$\alpha^{(2)}$	per °C x 10 ⁻³			25			
ϵ							

(1) At 25°C.

(2) Between 18°C and temperature indicated.

Iss. No.	1	
Date	JULY '61	
App'd by	AT	

STATIC PROPERTIES

(SHEET)

U.S.
AZ92A
Magnesium Alloy

Data Basis: A

Units: 10^3 lb./in.^2

Iss. No	1	2
Date	JULY '61	APRIL '62
App'd by	AT	AT

Footnotes										Form										Sand and permanent mould castings																																																	
Footnotes										Specification										QQ-M-56 QQ-M-55										AMS 4434																																							
										Condition										F										T4										T5										T6																			
Footnotes										Thickness (in.)																																																											
										Type of Test										0										0										0										0										0									
Footnotes										F _{1u}										20										34										20										34																			
										F _{1v}										10										10										11										18																			
Footnotes										F _{cl}																																																											
										F _{cy}										10										10										11										18																			
Footnotes										F _{cs}																																																											
										F _{su}										16										17																				20																			
Footnotes										F _{bu}										32										48																				52																			
										F _{bu}										42										58																				70																			
Footnotes										F _{bu}										30										32																				45																			
										F _{bu}										40										40																				55																			
Footnotes										E																				6,500																																							
										E _c																				6,500																																							
Footnotes										G																				2,400																																							
										e										%										6																				1																			
Footnotes										Footnotes																																																											

(1) Mechanical Properties are based on the minimum guaranteed tensile properties from separately cast test bars. The Mechanical Properties of production castings may be as low as 75 % of the tabulated values.

FATIGUE PROPERTIES

U.S.
AZ92A
Magnesium Alloy

Iss. No.	1		
Date	JULY 61.		
App'd by	AT		

Units: 10^3 lb./in.^2

Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles			
					10^5	10^6	10^7	10^8
					Nominal	Maximum	Stress	
	Rotating Bending	0.3in. diameter machined and polished from casting.	F	-1.0	16 18	14 16	13 15	12 14
			T4	-1.0	16 20	14 18	13 17	12 15
			T6	-1.0	16 21	14 19	12 17	11 15
			T7	-1.0	18 20	16 17	14 15	13 14
	Reversed Flexure.	0.25in. thick cast specimens.	T4	-1.0	13 17	10 13	8 10	
	Repeated Axial Load	0.3in. diameter machined and polished from casting.	F	0.25	23 25	22 24	21 23	
			T4	0.25		29 33	28 32	
			T6	0.25	29 32	27 30	26 29	
	Footnotes							

U.S.
AZ92A
Magnesium Alloy

Data Basis: C

Units: hours, °F.

Iss. No.	1		
Date	JULY '51		
App'd by	AT		

[illegible]

**U.S.
AZ92A
Magnesium Alloy**

Units: hours, °F.

Iss. No.	1		
Date	AUG '22		
App'd by	A T		

[illegible]

GENERAL PROPERTIES

U.S.
HK 31A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Th	Zr	Zn	Cu	Ni				Other Elements		Other Impurities Total	Mg
									Each	Total		
Sheet	2.5	0.45							0.15	0.30		Remainder
Plate	4.0	1.0							Max.	Max.		
Castings	2.5	0.5	0.30	0.10	0.01						0.20	Remainder
	4.0	1.0	Max.	Max.	Max.						Max.	

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.79				
c	cal./(gm.°C)		0.25	0.25	0.26	0.28	0.30
K	cal.cm/(cm. ² sec. °C)	Sheet	0	0.252	0.265	0.283	
			H24	0.270	0.281	0.296	
		Casting	T6	0.219	0.240	0.260	
$\alpha^{(1)}$	per °C x 10 ⁻⁶				27		
ϵ							

(1) Value between 20 and 200°C.

Iss. No.	1	Date	July '61	App'd by	AT
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STATIC PROPERTIES
(SHEET 1)

U.S.
HK31A
Magnesium Alloy

Data Basis: A

Units: 10³lb./in.²

Iss. No.	1	2
Date	JULY '61	APRIL '62
App'd by	A.T.	A.T.

Form	Sheet and Plate	
Specification	Mil-M-26075	AMS 4384
Condition	O	H24
Thickness (in.)		
	0.016	0.251
	0.250	0.500
	0.500	1.000
	1.000	1.500
	1.500	2.000
	2.000	2.500
	2.500	3.000
	3.000	3.500
	3.500	4.000
	4.000	4.500
	4.500	5.000
	5.000	5.500
	5.500	6.000
	6.000	6.500
	6.500	7.000
	7.000	7.500
	7.500	8.000
	8.000	8.500
	8.500	9.000
	9.000	9.500
	9.500	10.000
	10.000	10.500
	10.500	11.000
	11.000	11.500
	11.500	12.000
	12.000	12.500
	12.500	13.000
	13.000	13.500
	13.500	14.000
	14.000	14.500
	14.500	15.000
	15.000	15.500
	15.500	16.000
	16.000	16.500
	16.500	17.000
	17.000	17.500
	17.500	18.000
	18.000	18.500
	18.500	19.000
	19.000	19.500
	19.500	20.000
	20.000	20.500
	20.500	21.000
	21.000	21.500
	21.500	22.000
	22.000	22.500
	22.500	23.000
	23.000	23.500
	23.500	24.000
	24.000	24.500
	24.500	25.000
	25.000	25.500
	25.500	26.000
	26.000	26.500
	26.500	27.000
	27.000	27.500
	27.500	28.000
	28.000	28.500
	28.500	29.000
	29.000	29.500
	29.500	30.000
	30.000	30.500
	30.500	31.000
	31.000	31.500
	31.500	32.000
	32.000	32.500
	32.500	33.000
	33.000	33.500
	33.500	34.000
	34.000	34.500
	34.500	35.000
	35.000	35.500
	35.500	36.000
	36.000	36.500
	36.500	37.000
	37.000	37.500
	37.500	38.000
	38.000	38.500
	38.500	39.000
	39.000	39.500
	39.500	40.000
	40.000	40.500
	40.500	41.000
	41.000	41.500
	41.500	42.000
	42.000	42.500
	42.500	43.000
	43.000	43.500
	43.500	44.000
	44.000	44.500
	44.500	45.000
	45.000	45.500
	45.500	46.000
	46.000	46.500
	46.500	47.000
	47.000	47.500
	47.500	48.000
	48.000	48.500
	48.500	49.000
	49.000	49.500
	49.500	50.000
	50.000	50.500
	50.500	51.000
	51.000	51.500
	51.500	52.000
	52.000	52.500
	52.500	53.000
	53.000	53.500
	53.500	54.000
	54.000	54.500
	54.500	55.000
	55.000	55.500
	55.500	56.000
	56.000	56.500
	56.500	57.000
	57.000	57.500
	57.500	58.000
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	58.500	59.000
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	64.500	65.000
	65.000	65.500
	65.500	66.000
	66.000	66.500
	66.500	67.000
	67.000	67.500
	67.500	68.000
	68.000	68.500
	68.500	69.000
	69.000	69.500
	69.500	70.000
	70.000	70.500
	70.500	71.000
	71.000	71.500
	71.500	72.000
	72.000	72.500
	72.500	73.000
	73.000	73.500
	73.500	74.000
	74.000	74.500
	74.500	75.000
	75.000	75.500
	75.500	76.000
	76.000	76.500
	76.500	77.000
	77.000	77.500
	77.500	78.000
	78.000	78.500
	78.500	79.000
	79.000	79.500
	79.500	80.000
	80.000	80.500
	80.500	81.000
	81.000	81.500
	81.500	82.000
	82.000	82.500
	82.500	83.000
	83.000	83.500
	83.500	84.000
	84.000	84.500
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	93.500	94.000
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	96.000	96.500
	96.500	97.000
	97.000	97.500
	97.500	98.000
	98.000	98.500
	98.500	99.000
	99.000	99.500
	99.500	100.000
	100.000	100.500
	100.500	101.000
	101.000	101.500
	101.500	102.000
	102.000	102.500
	102.500	103.000
	103.000	103.500
	103.500	104.000
	104.000	104.500
	104.500	105.000
	105.000	105.500
	105.500	106.000
	106.000	106.500
	106.500	107.000
	107.000	107.500
	107.500	108.000
	108.000	108.500
	108.500	109.000
	109.000	109.500
	109.500	110.000
	110.000	110.500
	110.500	111.000
	111.000	111.500
	111.500	112.000
	112.000	112.500
	112.500	113.000
	113.000	113.500
	113.500	114.000
	114.000	114.500
	114.500	115.000
	115.000	115.500
	115.500	116.000
	116.000	116.500
	116.500	117.000
	117.000	117.500
	117.500	118.000
	118.000	118.500
	118.500	119.000
	119.000	119.500
	119.500	120.000
	120.000	120.500
	120.500	121.000
	121.000	121.500
	121.500	122.000
	122.000	122.500
	122.500	123.000
	123.000	123.500
	123.500	124.000
	124.000	124.500
	124.500	125.000
	125.000	125.500
	125.500	126.000
	126.000	126.500
	126.500	127.000
	127.000	127.500
	127.500	128.000
	128.000	128.500
	128.500	129.000
	129.000	129.500
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	135.500	136.000
	136.000	136.500
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	141.500	142.000
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	143.500	144.000
	144.000	144.500
	144.500	145.000
	145.000	145.500
	145.500	146.000
	146.000	146.500
	146.500	147.000
	147.000	147.500
	147.500	148.000
	148.000	148.500
	148.500	149.000
	149.000	149.500
	149.500	150.000
	150.000	150.500
	150.500	151.000
	151.000	151.500
	151.500	152.000
	152.000	152.500
	152.500	153.000
	153.000	153.500
	153.500	154.000
	154.000	154.500
	154.500	155.000
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	155.500	156.000
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	156.500	157.000
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	158.500	159.000
	159.000	159.500
	159.500	160.000
	160.000	160.500
	160.500	161.000
	161.000	161.500
	161.500	162.000
	162.000	162.500
	162.500	163.000
	163.000	163.500
	163.500	164.000
	164.000	164.500
	164.500	165.000
	165.000	165.500
	165.500	166.000
	166.000	166.500
	166.500	167.000
	167.000	167.500
	167.500	168.000
	168.000	168.500
	168.500	169.000
	169.000	169.500
	169.500	170.000
	170.000	170.500
	170.500	171.000
	171.000	171.500
	171.500	172.000
	172.000	172.500
	172.500	173.000
	173.000	173.500
	173.500	174.000
	174.000	174.500
	174.500	175.000
	175.000	175.500
	175.500	176.000
	176.000	176.500
	176.500	177.000
	177.000	177.500
	177.500	178.000
	178.000	178.500
	178.500	179.000
	179.000	179.500
	179.500	180.000
	180.000	180.500
	180.500	181.000

STATIC PROPERTIES
(SHEET 2)

U.S.
HK31A
Magnesium Alloy

Data Basis: A

Units: 10³lb./in.²

Iss. No.	1	2	
Date	JULY '61	APRIL '62	
App'd by	A.T	A.T	

Form		Sand Castings																	
Specification		AMS4445 QQ-M-56																	
Condition		T 6																	
Thickness (in)																			
Cross - Sectional Area (in ²)																			
(1)	Type of Test	a																	
	F _{tu}	27																	
	F _{ty}	13																	
	F _{cl}																		
	F _{cy}	13																	
	F _{cs}																		
	F _{su}																		
	— F _{bru} %D=1.5																		
	— F _{bry} %D=2.0																		
	— F _{bry} %D=1.5																		
	— F _{bry} %D=2.0																		
	E	6,500																	
	E _c	6,500																	
	G	2,400																	
	e	% 4																	
	Footnotes																		

(1) Mechanical Properties are based the minimum guaranteed tensile properties from separately cast test bars. The Mechanical Properties of production castings may be as low as 75% of the tabulated values

U.S.
HK31A
Magnesium Alloy

iss. No.	1		
Date	JULY '61		
App'd by	AT		

Units: 10^3 lb./in.^2

Data Basis: C

[illegible]

**SHORT TIME PROPERTIES
AT ELEVATED TEMPERATURE
(SHEET)**

**U.S.
HK31A
Magnesium Alloy**

Data Basis: C

Units: hours, °F.

Iss. No.	t		
Date	AUG 62		
App'd by	AT		

Form	Sheet and Plate												Sand Casting											
Condition	H24												T6											
t →	Per Cent F _{tu}	Per Cent F _{ty}	Per Cent F _{cy}	Per Cent F _{su}	Per Cent F _{br} (1)	Per Cent E and E _c							Per Cent F _{tu}	Per Cent F _{ty}	Per Cent F _{cy}	Per Cent F _{su}	Per Cent F _{br}	Per Cent E and E _c						
T →	Per Cent F _{tu}	Per Cent F _{ty}	Per Cent F _{cy}	Per Cent F _{su}	Per Cent F _{br} (1)	Per Cent E and E _c							Per Cent F _{tu}	Per Cent F _{ty}	Per Cent F _{cy}	Per Cent F _{su}	Per Cent F _{br}	Per Cent E and E _c						
100	94	97	99	91	98	100							98	98	98			99						
200	76	86	96	79	88	96							92	94	94			97						
300	66	75	93	67	80	95							86	89	89			94						
400	61	69	88	50	71	89							81	83	83			92						
500	50	55	78	42	63	76							74	76	59			89						
600	32	25	41	35	49	58							63	66	16			85						

(1) $\eta_0 = 2.0$

**U.S.
HK31A
Magnesium Alloy**

Units: hours, °F

Iss. No.	1		
Date	AUG 82		
App'd by	A.T.		

[illegible]

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET)

U.S.
HK31A
Magnesium Alloy

Units: hours, °F.

Data Basis: C

CREEP DATA

Form		Sand Casting															
Condition		T 6															
t →		10	20	30	40	50	60	70	80	90	100	200	500	1000			
T ↓	Total Deformation Per Cent	Per Cent F_{tu} ($F_{tu} = 33 \times 10^3 \text{ lb./in.}^2$ at 78°F)															
400	0.2	33	32	32	32	31	30	30	29	29	28	28	27	27			
	0.5	46	46	45	45	45	45	45	45	45	45	44	43	42			
	1.0	50	50	49	49	49	49	49	48	48	48	48	48	48			
500	0.2	32	32	31	30	29	27	26	24	22	19	18	15	13			
	0.5	44	44	43	42	41	39	37	35	32	29	27	23	20			
	1.0	49	49	48	48	47	45	44	42	39	36	35	29	22			
550	0.2	28	27	25	24	23	21	19	18	15	14	12	9.4	7.6			
	0.5	41	41	39	38	35	31	29	26	22	19	16	12	9.7			
	1.0																
600	0.2	22	21	20	19	17	15	14	12	10	8.5						
	0.5	37	36	34	31	29	25	21	19	14	10						
	1.0	45	43	40	38	34	29	26	22	17	13						
660	0.2	21	18	15	13	11	8.9	7.1	5.7	3.8	3.0						
	0.5	29	25	21	18	15	12	9.4	7.6	5.3	4.1						
	1.0																

Iss. No.	1		
Date	AUG '62		
App'd by	A.T.		

GENERAL PROPERTIES

U.S.
M1A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Mn	Si	Ca	Cu	Ni						Others Total	Mg
All Forms	1-2 Min.	0-30 Max.	0-14 Max.	0-05 Max.	0-01 Max.						0-30 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.75				
c	cal./(gm.°C)		0.25				
K	cal.cm/(cm. sec.°C)			0.302	0.302	0.302	
$\alpha^{(1)}$	per °C x 10 ⁻⁶			25			
ϵ							

(1) Between 18°C and temperature indicated.

1	July '55	AT
Iss. No.	Date	App'd by

1st. No.	1	
Date	Aug '62	
App'd by	A.T.	

Units: 10³lb./in.²

Data Basis: A

STATIC PROPERTIES (SHEET 1)

U.S.
M1A
Magnesium Alloy

Footnotes	Form	Sheet
	Specification	AMS 4370
	Condition	O
	Thickness (in.)	0.020 0.250
		L 38
	F _{tu}	LT
		ST
		L
	F _{ty}	LT
		ST
	F _{cl}	
	F _{cy}	
	F _{cs}	
	F _{su}	
	F _{bru}	
	F _{bry}	
	E	
	E _c	
	G	
	e	% 12
	Footnotes	

U.S.
M1A
Magnesium Alloy

Units: 10^3 lb./in.^2

Iss. No.	1		
Date	AUG '62		
App'd by	AT		

[illegible]

GENERAL PROPERTIES

U.S.
ZK 60A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Zr	Mn					Other Elements Total	Other Impurities		Mg
									Each	Total	
Extrusions	4.8 — 6.2	0.45 Min.	0.15 Max.						0.05 Max.	0.20 Max.	Remainder
Forgings	4.8 — 6.2	0.45 Min.						0.30 Max			Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³		1.82				
c	cal./(gm.°C)		0.25				
K	cal.cm/(cm. ² sec. °C)	F	0.281				
		T5	0.289				
α	per °C x 10 ⁻⁶		(1) 25				
ϵ							

(1) at 40°C.

1	JULY '61	AT
Iss. No.	Date	App'd by

(SHEET)

Data Basis: A

Units: 10^3 lb./in.^2

Iss. No	1		
Date	JULY '61		
App'd by	A.T		

[illegible]

(1) For web sections of I beams and other extruded sections having

width to thickness ratio of 20 to 1 or greater.

The transverse properties longitudinal properties

FATIGUE PROPERTIES

U.S.
ZK60A
Magnesium Alloy

Iss. No.	1	
Date	JULY '61	
App'd by	AT.	

Units: 10^3 lb./in.^2

Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles				
					10 ⁶	10 ⁷	10 ⁸		
					Nominal	Maximum	Stress		
	Rotating Bending	0.3 in. diameter, machined and polished from extrusion.	F	-1.0	29	26	23	20	
					32	29	26	23	
		0.3 in. dia. machined and polished from forging.	T5	-1.0	26	21	18	17	
					35	29	26	23	
	Reversed Flexure	0.25 in. thick specimen from forging. (surface machined)	T5	-1.0	22	18	17	16	
					25	21	20	18	
	Repeated Axial Load	0.3 in. diameter, machined and polished from extrusion.	F	0.25	17	13	11		
					21	16	14		
					41	38	38		
			T5	0.25	45	42	42		
					42	41	40		
					48	45	44		
	Footnotes								

GENERAL PROPERTIES

U.S.
AM 100A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Si	Mn	Cu	Ni					Others	Mg
Castings	9.3 10.7	0.30 Max.	0.30 Max.	0.10 Min.	0.10 Max.	0.01 Max.					0.30 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100			
ω	gm./cm. ³		1.80				
c	cal./(gm.°C)						
K	cal.cm/(cm. ² sec. °C)						
α	per °C x 10 ⁻⁶						
ϵ							

Iss. No.	1		
Date	July '61		
App'd by	A.T.		

STATIC PROPERTIES
(SHEET)

U.S.
AM100A
Magnesium Alloy

Data Basis: A

Units: 10^3 lb./in.^2

Iss. No.	1	2
Date	JULY '61	APRIL '62
App'd by	A.T.	A.T.

Footnotes	Form	Permanent Mould Castings				
	Specification	QQ-M-55, AMS 4483				
	Condition	F	T4	T6	T6i	
	Thickness (in.)					
	Cross-Sectional Area (or weight)					
(1)	Type of Test	0	0	0	0	
	F_{tu}	20	32	34	34	
	F_{ty}	10	10	15	17	
	F_{cl}					
	F_{cy}	10	10	15	17	
	F_{c5}					
	F_{su}					
	F_{bru}					
	F_{bry}					
	E	6,500				
	E_c	6,500				
	G	2,400				
	e		6	2		
	%					
	Footnotes					

(1) Mechanical Properties are based on the minimum guaranteed tensile properties from separately cast test bars. The Mechanical Properties of production castings may be as low as 75% of the tabulated values.

GENERAL PROPERTIES

U.S.
Inconel X.
Nickel Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	Mn	Si	S	Cr	Co	Ti	Cu	Al	Fe	Cb (Nb)		Ni and Co
All Forms	0.08 Max.	1.00 Max.	0.50 Max.	0.01 Max.	14.0 17.0	1.0 Max.	2.25 2.75	0.50 Max.	0.40 1.00	5.00 9.00	0.70 1.20		70.0 Min.

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	200	400	600	800
ω	gm./cm. ³	Fully HT	8.25	8.20	8.11	8.04	7.94
c	cal./(gm.°C)	Fully HT	0.103	0.116	0.124	0.133	0.157
K	cal.cm/(cm. ² sec. °C)	Fully HT	0.028	0.034	0.040	0.047	0.054
α	per °C x 10 ⁻⁶	Fully HT	12.4	12.9	13.8	14.9	16.2
ϵ	per cent	Oxydised Surface	12	13	15	18	26
		As Received, Cleaned	9	11.5	14.5	18	22
		Polished.	6	8	11.5	16	19
		Total Hemispherical after 30 min. Oxydisation at 2000°F			9	9	9

Iss. No.	1	Date	July '61	App'd by	A.T.

Ins. No.	1
Date	AUG '62
App'd by	A.T.

Units: 10^3 lb./in.^2

Data Basis: A

Form	Sheet	Strip
Specification	Mil-N-7786, AMS 5542	AMS 5542
Condition	Precipitation heat treated.	
Thickness (in.)		< 0.010 0.010 0.024
F_{tu}	L 155 LT 155 ST	150 155
F_{ty}	L 100 LT 100 ST	
F_{cl}	L	
F_{cy}	L 105 LT 105 ST	
F_{cs}	L	
F_{su}	108	
F_{bru}	$\%D=15$ $\%D=20$ 286	
F_{bry}	$\%D=15$ $\%D=20$ 186	
E	31,000	
E_c		
G	11,000	
e	% 20	15
Footnotes		

(1) Dynamic modulus. Data Basis C

STATIC PROPERTIES (SHEET 1)

U.S.
Inconel X
Nickel Alloy

Iss. No.	1		
Date	Aug '62		
App'd by	AT		

Units: 10^3 lb./in.^2 Data Basis: A

STATIC PROPERTIES (SHEET 2)

U.S.
Inconel X
Nickel Alloy

Form	Bar, Forgings										
Specification	AMS 5667										
Condition	Precipitation heat treated										
Thickness (in.)	< 4.0 ≥ 4.0										
Cross-Sectional Area (in. ²)											
F_{tu}	L T	165	165								
F_{ty}	L T	105	100								
F_{cl}											
F_{cy}	L T										
F_{cs}											
F_{au}											
F_{bru}											
F_{bry}											
E											
E_c											
G											
e	%	20	15								
Footnotes	(1)	(1)	(1)								

(1) Gauge length = 4 D. For specimens cut from near the centre of large disc forgings 'e' may be as low as 10%.

**U.S.
Inconel X
Nickel Alloy**

Units: hours, °F, 10³lb./in.²

Iss. No.	1		
Date	AUG '62		
App'd by	A. T.		

[illegible]

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET)

U.S.
Inconel X
Nickel Alloy

Units: hours, °F.

Data Basis: C

CREEP DATA

Form		Bar								Sheet							
Condition		Fully heat treated															
t →			-	0	0	0					-	0	0	0			
T ↓	Total Deformation Per Cent	Per cent F_{tu} (F_{tu} at R.T. = 162×10^3 lb./in. ²)								Per cent F_{tu} (F_{tu} at R.T. = 160×10^3 lb./in. ²)							
1200	0.2																
	0.5			49	44	40											
	1.0			51	46	41											
1350	0.2		27	26	23	20					24	19					
	0.5		33	32	28	22					33	27	19				
	1.0		38	34	29	23						29	21				
1500	0.2			17	14	9					16	11					
	0.5				16	10					18	14	7				
	1.0										19	16	9				
1600	0.2			8	6												
	0.5			8	6												
	1.0			9	6												

Iss. No.	1		
Date	AUG 62		
App'd by	A.T.		

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET 2)

U.S.
Inconel X
Nickel Alloy

Units: hours, °F.

Data Basis: C

MINIMUM CREEP RATE

Form												
Condition												
Creep Rate												
↓												

TIME TO TENSILE FAILURE

Form	Bar											
Condition	Fully heat treated											
t →	10 ⁻¹	1	10	10 ²	10 ³	10 ⁴						
T ↓	Per Cent F _{tu} (F _{tu} at 80°F = 162 x 10 ³ lb./in. ²)											
1000			75	72	67	62						
1100			68	61	55	49						
1200			52	49	42	35						
1350		47	37	31	25	18						
1500	32	26	22	16	11	5						
1600		14	11	7	4	1						

Iss. No.	1	
Date	Aug '82	
App'd by	AT	

GENERAL PROPERTIES

U. S.
COMMERCIALLY PURE
TITANIUM

CHEMICAL COMPOSITION (per cent)

Form	C	N	O	H							Others Total	Ti
Sheet, Strip, Plate, Tubing	0.20 Max.	0.07 ⁽¹⁾ Max.		0.015 Max.							0.60 ⁽²⁾ Max.	Remainder
Bars, Forgings	0.20 Max.	0.07 Max.	0.40 Max.	0.0125 Max.							0.80 Max.	Remainder

(1) Tubing only. (2) For AMS 4901 and Mil-T-7993 Cl. I, 0.80 Max.

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	gm./cm. ³	Ann.	4.54				
C	cal./(gm.°C)	Ann.	0.125	0.130	0.135	0.143	0.152
K	cal.cm./(cm. ² sec. °C)	99+Ti Ann.	0.047	0.044	0.043	0.043	0.043
		99 Ti Ann.	0.041	0.041	0.041	0.041	0.041
α	per °C x 10 ⁻⁶	Ann.		8.73	9.36	9.54	9.72
ϵ							

Iss. No.	Date	App'd by
1	JULY '61	AT

STATIC PROPERTIES

(SHEET 1)

U.S.
COMMERCIALLY PURE
TITANIUM

Data Basis: A

Units: 10^3 lb./in.^2

Iss. No.	1	
Date	AUG 62	
App'd by	AT	

Footnotes	Form	Sheet, strip, plate.						Welded tubing			
	Specification	Mil-T-7993		AMS 4902 (Ti-40)	AMS 4900 (Ti-55)	AMS 4901 (Ti-70)	AMS 4941 (Ti-40)				
		(99+Ti)	(99Ti)								
								Ann.			
Condition											
Thickness (in.)											
F _{tu}	L	60	80	50	65	80	50				
	LT	60	80								
	ST										
F _{ty}	L	50	70	40	55	70	40				
	LT	50	70								
	ST										
F _{cl}	L	50	70								
	LT										
	ST										
F _{cs}	L	50	70								
	LT										
	ST										
F _{su}	L	50	70								
	LT										
	ST										
F _{bru}	L	50	70								
	LT										
	ST										
F _{bry}	L	50	70								
	LT										
	ST										
E	L	50	70								
	LT										
	ST										
E _c	L	50	70								
	LT										
	ST										
G	L	50	70								
	LT										
	ST										
Footnotes	L	50	70								
	LT										
	ST										

(1) F_{ty} max. = 65 (2) F_{ty} max. = 80 (3) F_{ty} max. = 95

U.S.
COMMERCIALLY PURE
TITANIUM

Units: 10^3 lb./in.^2

Iss. No	1		
Date	AUG '62		
App'd by	A 1		

Footnotes	Form	Bar, Forgings																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
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SHORT TIME PROPERTIES
AT ELEVATED TEMPERATURE
(SHEET)

U.S.
Commercially Pure
Titanium

Iss. No.	1
Date	AUG '62
App'd by	AT

Units: hours, °F, 10³ lb./in.² Data Basis: C

Form																
Condition	Ann.															
t →	90	001	90	001	90	001	90	001	90	001	90	001	90	001	90	001
T ↓	Per Cent F _{tu}	Per Cent F _{ty}	Per Cent F _{cy}	Per Cent F _{su}	Per Cent F _{bu}	Per Cent F _{by}	Per Cent E (15400 at 80°F)	90	001	Per Cent F _{tu}	Per Cent F _{ty}	Per Cent F _{cy}	Per Cent F _{su}	Per Cent F _{bu}	Per Cent F _{by}	
200	79	79	76	76	69	69	84	84	81	81	81	97				
300	66	66	59	59	54	54	73	73	67	67	67	93				
400	57	56	46	46	45	45	63	63	56	56	56	90				
500	50	48	37	37	45	45	56	56	48	48	48	85				
600	45	42	32	31	45	44	50	50	43	43	43	81				
700	40	37	28	26	44	40	46	45	40	40	40	77				
800	36	33	26	22	41	35	42	40	39	35	35	72				
900	33	29	23	19	36	32	37	34	34	30	30	68				
1000	30	26	20	16	30	29	31	27	26	25	25	64				

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET)

**U.S.
Commercially Pure
Titanium**

Units: hours, °F, 10^3 lb./in.^2

Data Basis: C

CREEP DATA

Form		Ti-70 Sheet															
Condition		Ann.															
t →		0.001	0.002	0.005	0.01	0.02	0.05	0.1	0.2	0.5	1	2	5	10			
T ↓	Total (1) Deformation Per Cent	Per Cent F_{tu} (90 at Room Temperature)															
600	2			35	34	33	33	33	33	33	33	33	32				
	3			42	36	35	34	34	34	34	34	34	33				
	5				38	36	36	35	35	35	34	34	34				
	7				42	39	37	36	36	36	36	36	35				
800	2				31	29	28	28	27	27	27	27	27				
	3									31	30	29	28				
	5										33	31	29				
	7																
1000	2				20	19	19	17	14	13	12	12	11				
	3				20	20	20	18	16	14	13	12	12				
	5				20	20	20	19	18	16	14	13	12				
	7					21	20	20	19	17	14	13	13	12			
1200	2				9.7	8.5	7.2	5.2	4.3	3.9	3.6	3.4					
	3				10	9.3	8.5	7.0	5.6	4.6	3.9	3.6	3.4				
	5				10	9.9	9.4	8.3	6.5	5.3	4.2	3.8	3.5				
	7					10	9.8	8.9	7.6	6.0	4.7	4.0	3.7	3.4			

(1) Including thermal expansion and elastic extension.

Iss. No.	1		
Date	AUG 62		
App'd by	A.T.		

GENERAL PROPERTIES

U. S.
8 Mn
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Mn	C	O	N	H						Others	Ti
Sheet, Strip and Plate.	6.50 9.00	0.20 Max.	0.20 Max.	0.07 Max.	0.015 Max.						0.60 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	200	400	600	800
ω	gm./cm. ³		4.74				
c	cal./(gm.°C)		0.118	0.14	0.155	0.18	0.21
K	cal.cm/(cm. ² sec. °C)		0.026	0.031	0.036	0.042	
$\alpha^{(1)}$	per °C x 10 ⁻⁶			9.1	10.1	11.2	12.4
ϵ							

(1) Between room temperature and temperature indicated.

Iss. No.	Date	App'd by
1	July '61	A.T.

**U.S.
8 Mn
Titanium Alloy**

Data Basis: A

Units: 10^3 lb./in.^2

Iss. No.	1		
Date	AUG '62		
App'd by	AT		

Footnotes		Form	Sheet, Strip and Plate.
Specification		Mil-T-009046 Cl.I, AMS 4908	
Condition		Ann	
Thickness (in.)			
F _{tu}		L 120	
		LT 120	
		ST	
F _{ty}		L 110	
		LT 110	
		ST	
F _{cl}			
F _{cy}		L 110	
		LT 110	
		ST	
F _{cs}			
F _{su}		84	
F _{bru}		$\frac{7}{8}$ D±1.5 170	
		$\frac{7}{8}$ D±2.0	
F _{bry}		$\frac{7}{8}$ D±1.5 130	
		$\frac{7}{8}$ D±2.0	
E		15,500	
E _c		16,000	
G			
e		% 10	
Footnotes			

U. S.
8 Mn
Titanium Alloy

Units: 10^3 lb./in.^2

Iss. No.	1		
Date	AUG '62		
App'd by	A.T.		

[illegible]

SHORT TIME PROPERTIES
AT ELEVATED TEMPERATURE
(SHEET)

U.S.
8Mn
Titanium Alloy

Data Basis: C

Units: hours, °F.

Iss. No.	1	
Date	AUG '62	
App'd by	AT	

Form	Sheet, Strip, Plate.													
Condition	Ann.													
t →	0001 VI	0001 VI	0001 VI	0001 VI	0001 VI	0001 VI	0001 VI	0001 VI	0001 VI	0001 VI	0001 VI	0001 VI	0001 VI	0001 VI
T ↓	Per Cent F _{tu}	Per Cent F _{ty}	Per Cent F _{cy}	Per Cent F _{su}	Per Cent F _{bry}	Per Cent E and E _c								
200	93	83	84	93	89	95								
300	87	73	74	88	81	91								
400	83	66	66	84	75	87								
500	79	62	62	79	71	84								
600	76	60	60	75	68	80								
700	71	56	56	71	64	76								
800	63	48	49	68	59	71								
900	50	36	38		50	60								
1000	30	22	22		33	38								

GENERAL PROPERTIES

U.S.
4Al-4Mn
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Mn	Fe	O	C	N	H				Others	Ti
Bars and Forgings	3.0 5.0	3.0 5.0	0.5 Max.	0.20 Max.	0.15 Max.	0.07 Max.	0.0125 Max.				0.40 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	200	400	600	800
ω	gm./cm. ³		4.51				
C	cal./(gm.°C)		0.13	0.14	0.155	0.175	0.195
K	cal.cm/(cm. ² sec. °C)		0.0165	0.022	0.029	0.036	0.045
$\alpha^{(1)}$	per °C x 10 ⁻⁶			8.9	9.3	9.9	10.4
ϵ							

(1) Between room temperature and temperature indicated.

Iss. No.	Date	App'd by
1	JULY '61	A.T.

STATIC PROPERTIES
(SHEET)

U.S.
4Al-4Mn
Titanium Alloy

Data Basis: A

Units: 10^3 lb./in.^2

Iss. No.	1	2
Date	JULY 61	AUG 62
App'd by	AT	AT

Form	Bar
Specification	Mil-T-9047 Cl.6; AMS 4925
Condition	Ann.
Thickness (in.)	
Diameter (in.)	≤ 3
F_{tu}	L 140 T
F_{ty}	L 130 T
F_{cl}	
F_{cy}	
F_{cs}	
F_{su}	
F_{bru}	
F_{bry}	
E	15,500
E_c	16,000
G	7,400
e	% 12
Footnotes	

(1) Data Basis: C (2) AMS 4925 gives e = 10%

FATIGUE PROPERTIES

U.S.
4Al-4Mn
Titanium Alloy.

Iss. No.	1		
Date	AUG. '62		
App'd by	A T		

Data Basis: C

Units: 10^3 lb./in.^2

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles			
					10 ⁵	10 ⁶	10 ⁷	
					Nominal	Maximum	Stress	
Rotating Bending	Smooth Bar	Ann. ($F_{tu} = 158$)	-1.0	108	101	101		
				40	36	36		
	Smooth Bar	Aged ($F_{tu} = 172$)	-1.0	112	108	108		
				51	45	45		
Reversed Flexure	Smooth Bar	Ann.	-1.0		86	86		
Footnotes								

SHORT TIME PROPERTIES
AT ELEVATED TEMPERATURE
(SHEET)

U.S.
4Al-4Mn
Titanium Alloy

Data Basis: C

Units: hours, °F, 10³ lb./in.²

Iss. No.	1		
Date	AUG '62		
App'd by	AT		

Form	Bar													
Condition	Ann.													
t →	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
T ↓	Per Cent F _{tu} (155 at R.T.)	Per Cent F _{ty} (144 at R.T.)	Per Cent F _{cy} (130 at R.T.)	Per Cent F _{su} (84 at R.T.)	Per Cent F _{br} (6,600 at R.T.)	Per Cent E								
200	90	88				96								
300	86	81				93								
400	81	75				90								
500	77	71	74	80		87								
600	74	67	72	76		83								
700	71	63				80								
800	66	57				77								
900	57	47				74								
1000	47	33				70								

**PROPERTIES UNDER LOAD
AND ELEVATED TEMPERATURE**
(SHEET)

U.S.
4Al-4Mn
Titanium Alloy

Units: hours, °F, 10^3 lb./in.^2

Data Basis: C

MINIMUM CREEP RATE

Form												
Condition												
Creep Rate												
↓												

TIME TO TENSILE FAILURE

Form	Bar											
Condition	Ann.											
t →	0.1	1	10	100	1000							
T ↓	Per Cent F_{tu} (140 at R.T.)											
80	97		91	88.5	84							
200	86		84	81.5	73.6							
400	77.5		75	73.5	71							
600	71		68	66	61							
800	64.5		56.5	48.5	30							

Iss No	1	
Date	Aug 62	
App'd by	AT	

GENERAL PROPERTIES

U.S.
6Al-4V
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	V	Fe	O	C	N	H				Others	Ti
Sheet, Strip and Plate.	5.50 6.75	3.50 4.50	0.30 Max.	0.15 Max.	0.10 Max.	0.05 Max.	0.015 Max.				0.40 Max.	Remainder
Bars and Forgings.	5.50 6.75	3.50 4.50	0.30 Max.	0.15 Max.	0.10 Max.	0.05 Max.	0.0125 Max.				0.40 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	200	400	600	800
ω	gm./cm. ³		4.43				
C	cal./(gm.°C)		0.135	0.135	0.138	0.143	0.153
K	cal.cm/(cm. ² sec. °C)		0.0157	0.0165	0.0214	0.0248	0.0278
$\alpha^{(1)}$	per °C x 10 ⁻⁶			8.4	8.6	8.8	9.1
ϵ							

(1) Between room temperature and temperature indicated

Iss. No.	1	July '61	A.T.
Date			
App'd by			

(SHEET 1)

Iss. No.	1	
Date	July '87	
App'd by	A.T	

Data Basis: A

Units: 10^3 lb./in.^2

Form	Sheet, strip.
Specification	AMS 4911, Mil-T-009046 CL2
Condition	Ann.
Thickness (in.)	≤ 0.187
F _{TU}	L 130 LT 130 ST
F _{TY}	L 120 LT 120 ST
F _{CL}	L 126 LT 126 ST
F _{C5}	76
F _{SU}	(°D±1.5) 191 (°D±2.0) 244 (°D±1.5) 163 (°D±2.0) 198
E	L 15,400 T 16,400
E _c	L 16,000 T 16,900
G	% 10
Footnotes	

**U.S.
GAL - 4V
Titanium Alloy**

Data Basis: A

Units: 10^3 lb./in.^2

Iss. No	1		
Date	JULY '61		
App'd by	A T		

Form	Bar
Specification	Mil-T-9047 Class 5, AMS 4928
Condition	Ann.
Thickness (in.)	≤ 1.5
Gross-Sectional Area (in. ²)	
F_{tu} L T	130
F_{ty} L T	120
F_{cl}	
F_{cy} L T	126
F_{c5}	
F_{su}	80
F_{bru} (%D=1.5)	196
F_{bru} (%D=2.0)	248
F_{bry} (%D=1.5)	174
F_{bry} (%D=2.0)	205
E	16,000
E_c	16,400
G	6,200
ϵ %	10
Footnotes	

SHORT TIME PROPERTIES
AT ELEVATED TEMPERATURE
(SHEET)

U.S.
6 Al - 4 V
Titanium Alloy

Iss. No.	1
Date	AUG '92
App'd by	A.T.

Data Basis: C

Units: hours, °F

Form	Sheet and Bar									
Condition	Ann.									
t →	001 VI	001 VI	001 VI	001 VI	001 VI	001 VI	001 VI	001 VI	001 VI	001 VI
T ↓	Per Cent F _{tu}	Per Cent F _{ty}	Per Cent F _{cy}	Per Cent F _{su}	Per Cent F _{dy}	Per Cent E _{ant}	Per Cent E _{ec}			
200	90	86	90	92	87	94				
300	85	79	83	87	81	91				
400	81	74	76	82	76	88				
500	78	70	71	78	72	84				
500	76	67	67	75	69	81				
700	72	64	64	73	67	78				
800	67	60	63	70	65	74				
900	61	54	58	65	61	67				
1000	54	45	48	57	54	49				

U.S.
6Al-4V
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Units: hours, °F, 10³lb./in.²

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App'd by	AT		

[illegible]